AMERICAN

INDUSTRIAL HYGIENE

ASSOCIATION

QUARTERLY

VOLUME 11 DECEMBER, 1950 NUMBER 4

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

AMERICAN
INDUSTRIAL HYGIENE
ASSOCIATION
QUARTERLY

Volume 11 DECEMBER, 1950 Number 4

CONTENTS

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY, an Official Publication of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, published quarterly (March, June, September, December) by INDUSTRIAL MEDICINE PUBLISHING COMPANY, Chicago (publishers also of INDUSTRIAL MEDICINE and SURGERY, issued monthly). STEPHEN G. HALOS, President; A. D. CLOUD, Publisher; DORIS FLOURNOY, Editorial Assistant; HAROLD A. HOOPER, Treasurer; STEPHEN G. HALOS, Advertising and Business Manager. PUBLICATION, EDITORIAL and EXECUTIVE Offices, 605 North Michigan Avenue, Chicago 11, Illinois. Subscription $2.00 per year in the United States; $2.50 per year in Canada; $3.00 per year in other countries. Single copies 75 cents.

Entered as second class matter May 3, 1948 at the post office at Sheboygan, Wis., under the Act of March 3, 1879.

AMERICAN
INDUSTRIAL HYGIENE
ASSOCIATION
QUARTERLY

Volume 11 | DECEMBER, 1950 | Number 4

Rapid Quartz Analysis By X-Ray Spectrometry

KINGSLEY KAY, M.A., PH.D.,
Chief, Industrial Health Laboratory,
Department of National Health and Welfare,
Ottawa, Canada

IN CANADA, where silicosis is the major occupational disease, it was found for many years that our capacity to diagnose and measure the severity of the quartz dust exposures was largely limited by the laboratory problem of estimating quartz in adequate numbers of field samples. Chemical estimation was impossible on the quantity basis necessary for effective health supervision. Serious limitations existed in the petrographic method.

The situation was greatly improved with the advent of the commercial x-ray powder cameras during the latter years of the war. In the post-war period, further speed became possible with the development of the x-ray Geiger counter spectrometer and during the last 18 months this laboratory has been able to extend without charge a quartz analytical service to responsible groups throughout Canada. This service has removed a heavy burden from hard-pressed Governmental agencies across the country and has been of special benefit to the small industries which are unable to afford their own laboratory services. It has extended the possibilities of reducing future silicosis and all that the disease implies in human suffering and economic cost.

The x-ray Geiger counter spectrometer was developed by Friedman[1] in 1945. Patterned after the ionizing chamber instrument described by the Braggs in 1921, it does away with time-consuming and variable photography and offers a high resolution geometry which eliminates many of the superpositional frustrations met with in use of powder cameras. It offers vast possibilities for quantitative analysis of crystallites.

The application of the instrument to free silica analysis was first reported by Klug, Alexander and Kummer[2] at the 1947 meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION.

These authors employed a Norelco spectrometer and studied instrument variation, sample preparation and reproducibility of results. A day-to-day compensable variation in instrument response was observed. The advantage of intensity measurement by counter technique over recorder was noted. Preference for binder-free packed specimens was expressed. These observations combined with a subsequent report[3] indicated that samples of $<5\mu$ particle size and of more than 10% quartz content could be analyzed with an accuracy of $\pm$ 5% for single counter determinations, though it was stressed that little saving in time could be effected over the powder camera technique. This paper describes new findings related to the use of the spectrometer as a rapid analytical service instrument; extended sample preparation techniques are discussed; analytical tractability of quartz over five micron size is demonstrated.

Paper presented at AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS, Chicago, April 24, 1950.

Fig. 1.
The Norelco Geiger Counter X-Ray Spectrometer

General Procedure

THE NORELCO spectrometer employed in this laboratory is shown in Fig. 1. For the data reported, a copper target tube with mica window was used with a mica window Geiger tube and nickel filter. Materials for analysis were prepared with fluorite as internal standard according to the technique described by Clark and Reynolds,[4] one part fluorite to two parts by weight of sample being the proportionality. The ratio of the diffraction maxima for the 3.33 Å spacing of quartz ($2\theta = 26.67°$) and 3.16 Å spacing of fluorite ($2\theta = 28.36°$) is taken as the measure of quartz content of sample in accordance with the findings of Klug and co-workers[3] who found diffraction maxima (I_Q/I_f) more valid than diffraction areas. Ratios obtained on unknown samples are compared with a calibration curve based on I_Q/I_f values for known quartz mixtures with calcite as diluent.

Recorder Operation

THE superior accuracy to be obtained with the spectrometer by employing the counting circuit is undisputed. This method, however, involves scanning the Geiger tube arm in what are generally 0.05° movements in order to obtain the data to plot a curve of intensity versus diffraction angle. The procedure is time-consuming and does not offer possibilities for rapid analysis.

The recording potentiometer with which the instrument is equipped permits rapid reproduction of a contour of diffraction intensity. It operates in conjunction with the goniometer arm which can be motor driven at 2° per minute. In the case of quartz analysis the area of interest lies between 24° and 30° (2θ). For this arc production of a diffraction contour requires only three minutes, but, as shown by Klug and co-workers,[2,3] the recorder is subject to considerable variation. Therefore, in this study, the extent of compromise which the recorder makes between accuracy and speed was explored to determine the security of results in an analytical technique based on recorder operation.

Fig. 2 shows the recorder trace over the arc 24-30° (2θ) for a mixture of quartz calcite and fluorite. In this laboratory estimation of quartz responses as I_Q/I_f involves completing the curves to base line (back-

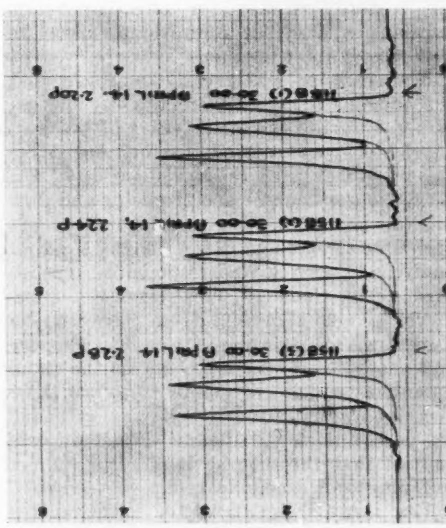

Fig. 2.
Recorder trace for quartz-calcite-fluorite mixture covering goniometer angles 24° to 30°. Sample contains 33-1/3% quartz in absolute terms, 50% on internal standard basis

ground radiation intensity) as shown by the dotted lines in Fig. 2. This method was adopted to compensate for the effect on maxima of partially superposing contours. The ratios so calculated have been found to be independent of scanning speed. It has been found that estimation of peak heights can be made within the range of variation which current slide preparation techniques and other variables enforce. That the method will be dependent upon goniometer adjustment will be clear from the work of Alexander[5] and Birks[6] who have independently shown that symmetry of contours is a function of instrument geometry.

Instrument variation under recorder operation was investigated by studying the variability of the ratio I_Q/I_f for mixtures of quartz, calcite, and fluorite. Fig. 2 shows the trace for a mixture corresponding to a 50% quartz sample. Such a specimen and others of different quartz content were employed to establish the pattern of variation in instrument response. A marked point on each specimen permitted repositioning on the same sample area thus eliminating possible variations due to surface differences from area to area on the same specimen.

Day-to-day variation was studied over a three-week period of observation. Single traces for identical specimens were found to vary as much as $\pm$ 15%, but no consistent pattern of daily change could be delineated for this particular instrument. I_Q/I_f values determined from twelve consecutive traces recorded within the first, second, and fifth hour of operation on a single day were found to have the following variation $0.83 \pm 8\%$; $0.79 \pm 9\%$; and $0.83 \pm 4\%$. Averages of 12 traces recorded in the seventh hour of one particular day and the first hour of the following day agreed as follows: $0.77 \pm 7\%$ and $0.80 \pm 12\%$. These examples reveal the considerable variation between single consecutive traces on an identical specimen but do not point to hourly variations. They show, furthermore, that I_Q/I_f is largely immune to a drop in intensity of any given diffraction beam which has been found to occur consistently during the first 90 minutes of operation of the instrument each day.

As no considerable day-to-day or hour-to-hour variation in the value of I_Q/I_f was discovered, an exploration was made of the variability within hourly periods. For this purpose sets of 12 consecutive traces were run on a series of specimens. As Table I shows this was carried out with four specimens covering concentrations 3%, 25%, 50% and 75%. It is evident that the variation between single traces is greater when quartz content is low for the reason that low deflection for the quartz spacing 3.33 Å is experienced by the recorder. However, the single trace variation decreases in importance when it is observed that averages of two, three and six traces display a markedly reduced variation. As the time taken to record a trace is but three minutes in this method of quartz analysis, it is apparent that attainment of acceptable variability by multiplication becomes a practical possibility under recorder operation.

TABLE I.
RECORDER TRACE VARIATION
AS PERCENTAGE OF I_Q/I_f

%	Average of Consecutive Traces Total of Twelve			
Quartz	Singles	Twos	Threes	Sixes
3	0.07 ± 15	" ± 10	" ± 6	" ± 0.1
25	0.39 ± 20	" ± 13	" ± 8	" ± 2.5
50	0.80 ± 10	" ± 5	" ± 4	" ± 4
75	1.20 ± 5	" ± 4.5	" ± 4	" ± 3

The ratio I_Q/I_f has been found to defy various instrumental factors, electrical and geometric. It is, however, significantly sensitive to damping and amplitude adjustments as has been noted by McCreary.[7] In this laboratory it has been found that when recorder deflection is low, as in the case of low quartz samples, ratios may be caused to vary by as much as 100% through damping and amplitude manipulation which will not appreciably affect I_Q/I_f for a 50% specimen. Standard damping and amplitude conditions are required to eliminate this important instrumental variant beyond the control of the internal standard technique.

The Diffraction Specimen

METHODS OF SPECIMEN preparation are as yet scantily dealt with in the literature of the X-ray spectrometer. The at-

TABLE II.
SPECIMEN UNIFORMITY
< 5 MICRON BINDER-FREE
QUARTZ — CALCITE — FLUORITE

Specimen	% Quartz	I_Q/I_f at Specimen Position (1)	(2)	(3)	Average	Plot
B 213	6	0.25	0.21	0.20	0.22	
B 214	6	0.20	0.19	0.23	0.21	Resurfaced 0.24
B 215	6	0.36	0.28	0.20	0.28	0.24
B 207	12	0.75	0.67	0.70	0.71	0.74
B 208	12	0.82	0.83	0.63	0.76	Resurfaced 0.81
B 209	50	1.99	1.73	1.69	1.80	1.73
B 210	50	1.78	1.61	1.58	1.66	Resurfaced 1.70
B 211	75	2.26	2.44	2.31	2.34	2.32
B 212	75	2.21	2.48	2.19	2.29	Resurfaced 2.33
B 220	100	2.84	2.68	3.27	2.93	
B 221	100	3.33	2.80	2.80	2.96	2.94
B 223	100	2.60	3.20	3.02	2.94	Resurfaced 2.90

tainment of flat specimen surfaces possessing the uniformity necessary for quantitation tends to be a special problem with particular crystallites and related mixtures. In 1943 Ballard, Oshry and Schrenk[8] studied grinding and mixing of quartz powders for powder camera analysis. Generally, their findings apply to the preliminary work-up of material for quartz analysis by spectrometry. Klug and co-workers[2,3] reported in 1948 that $< 5\,\mu$ particle size was necessary for uniformity of diffraction by quartz powder surfaces. In this laboratory, work was undertaken to develop quantitative analysis on quartz powder specimens of large particle size ($<$ 200 mesh) with a view to reducing time required to prepare smaller diameter material by the time-consuming settling or grinding techniques. It was felt that analytical data on large particle size material would be of value even though the $< 5\mu$ range was currently the fraction of toxicological interest.

Specimen Preparation Without Binder Material

A COMMON METHOD for preparing spectrometer specimens is to pack powders in a depression in a glass or metal slide. A flat powder surface on a level with the supporting slide must be ensured, for variations in powder surface level disturb the critical relationship between source, specimen and slit, which is necessary for focusing and maximal instrument response. In this laboratory the powder is scraped level by means of an ordinary microscope slide. The danger of preferred orientation as a result of tight packing has already been mentioned by Klug's group who employed cavities of 0.8 mm. depth. On the other hand, light packing of their specimens will not always produce preparations capable of withstanding normal handling in the vertical position. On this account cavities of 1.75 mm. depth were routinely employed in this laboratory. The technique of McCreery[8] for preventing preferred orientation was essayed but it was found difficult to remove the glass back of the slide without taking away particles of powder when large size fractions were employed.

Table II shows I_Q/I_f ratios obtained at three different positions across the face of $< 5\mu$ specimens of different quartz content. The ratios are based upon a single recorder trace. It is noteworthy that variation of I_Q/I_f between the three slide positions frequently exceeds the single trace variation expected from the studies on recorder performance. This points to differences in uniformity of $< 5\,\mu$ specimen surfaces as regards flatness, particle size distribution, or composition. It will be noted that averaging the ratios for the three positions resulted in greatly improved agreement between duplicate or triplicate specimens. Attention is directed to the agreement between first and second surfacing shown in Table II.

Averaging among specimens produces values which on plotting in Fig. 3 show a close linear relationship between 100 and 12% quartz, but the straight line extrapolates through the ordinate. As theory dictates that the curve pass through the origin, the 6% point was explored. A change of direction toward the origin was found, but the 6% point fell below a straight line drawn between the origin and 12%. The phenomenon is reminiscent of the curvature reported by Klug et al[3] between 0 and 10% and further work is in progress

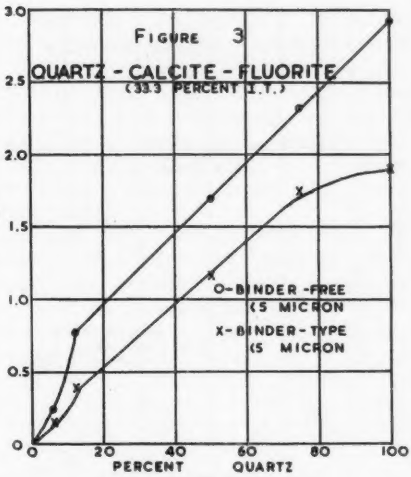

Fig. 3.

Relationship between percentage of quartz on internal standard basis and the ratio of intensities of quartz (d value 3.33 A°) and fluorite (d value 3.16 A°) for < 5 micron powder prepared by binder-free and binder techniques

to investigate this aspect as well as the displacement of the straight line portion. As will be later shown, sample preparation techniques play a major role in the agreement which can be reached between theory and experiment in diffraction analysis.

Work with < 200 mesh powders proved that this specimen preparation technique was unsuitable for the large particle size materials. Grinding in amyl acetate for 12 minutes improved the surface uniformity of diffraction but did not make it practicably possible to arrive at constant surface conditions for diffraction. This is demonstrated by results on resurfacing of specimens shown in Fig. 4.

Binder Type Preparation

WITH A VIEW to establishing a method which would permit the analysis of < 200 mesh material, experiments were undertaken with the binder type of preparation. Coating powders on glass slides by means of a binder is a well-known method of preparing a powder surface but at the time of this study, the method had not been exploited in quantitative analysis.

After investigation of various factors influencing the preparation of surfaces, the following procedure was evolved:

> 0.10 gram of specimen (< 200 mesh or < 5μ) is placed in an agate mortar of inside diameter 60 mm. permanently attached to the turntable of a Fisher grinder. To the mortar 0.5 c.c. (< 200 mesh powder) or 0.3 c.c. (< 5μ powder) of amyl acetate and 0.1 c.c. of collodion amyl acetate (1:1 by volume) are added. Sample is then ground at 22 ± 1°C. for a 12 minute period, when < 200 mesh powder is involved; three minutes in the case of < 5μ powder. At the end of this time, the contents of mortar are poured onto the centre of a one square inch area marked on a microscope slide, draining of the mortar being assisted by means of an agate pestle. The liquid is adjusted to cover one square inch by tipping the slide. Drying is carried out in an oven maintained at 39 ± 2°C. and takes under 10 minutes.

Sample weight and area of pour were found to be critical in avoiding preparations too thin for maximal diffraction or too thick for smooth drying. In the present

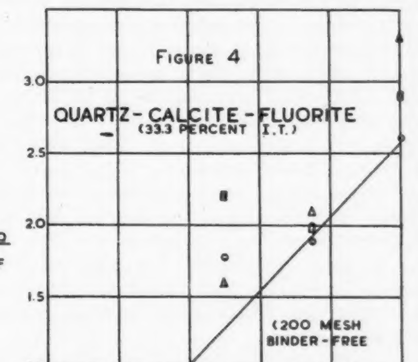

Fig. 4.

Relationship between percentage of quartz on internal standard basis and the ratio of intensities of quartz (d value 3.33 A°) and fluorite (d value 3.16 A°) for < 200 mesh powder prepared without binder. Resurfacing produces major changes in ratio

technique sample size and area control produce uniform thickness from preparation to preparation. The minimal thickness condition postulated by Taylor[9] appears to have been exceeded.

Collodion strength and viscosity of ground mixture were early noted to have an influence upon maximal diffraction. It was found necessary to maintain collodion at uniform strength and to grind under temperature control to prevent wide variation in consistency due to evaporation of amyl acetate and ether. In studies of large numbers of identical quartz preparations, it was noted that very thick and indeed very thin slides frequently gave diffraction intensities above average. Controlled drying proved necessary in maintaining consistent smoothness though wrinkled preparations did not consistently show lower than average diffraction.

Surfaces made up with unground < 200 mesh material exhibited extreme variation in reflectivity. Minimal grinding time for production of uniformly diffracting powders was therefore investigated. In experiments with < 200 mesh quartz ground in amyl acetate for periods up to 60 minutes major gains in maxima and specimen surface uniformity were made up to 10 minutes grinding. Thereafter little advantage resulted. Additionally, it was observed that the diffraction maxima of hand-ground specimens agreed with maxima of machine-ground provided that the mortar was not removed from an optimum position on the grinder turntable, for the machine grinder efficiency was found to be dependent upon the relationship between mortar and the pestle.

In view of the foregoing observations a standard grinding time of 12 minutes was selected except in the case of $< 5\mu$ material where three minutes in the mortar provides for mixing of pour. It is admitted that 200 mesh material may have highly variable particle size distribution and that in these circumstances variation from standard grind time might possibly be necessary to arrive at standard diffraction maxima. However, as will be shown later, synthetic mixtures of quartz, calcite and fluorite from $< 5\mu$, 5μ to 200 mesh and from < 200 mesh material have consistently yielded comparable diffraction

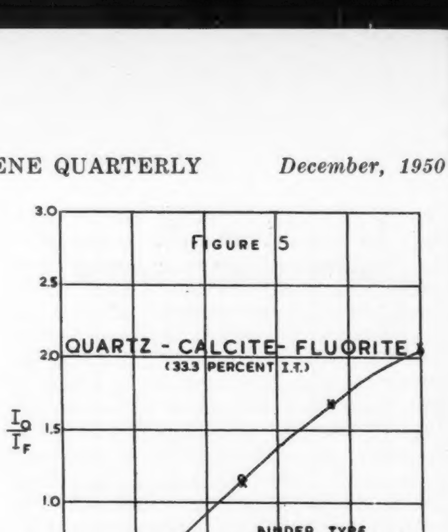

Fig. 5.
Relationship between percentage of quartz on internal standard basis and the ratio of intensities of quartz (d value 3.33 A°) and fluorite (d value 3.16 A°) for 200 mesh powder and 5μ to 200 mesh fraction prepared by binder technique

response indicating that minimal particle sizing for maximal diffraction has been attained. Further security is contributed to the standard grinding time from the fact that no cases of contour broadening or lowered maxima have been noted with the synthetic mixtures of these size ranges. Differences in diffraction response of fluorite from particular reagent lot numbers have been observed but contours have been narrow and high—atypical of very small particle size material. Finally, large numbers of samples of quartz reduced from large crystals to < 200 mesh size by nonstandard pulverizing techniques have proved to yield comparable diffraction maxima on 12 minute grinding. This, along with experience on a wide variety of field samples, established that effect of variation in large size proportion is resolved by the grinding period chosen.

Ratios for $< 5\mu$ mixtures of quartz, calcite and fluorite are summarized in Fig. 3. Diffraction estimations for mixtures in the size ranges 5μ – 200 mesh and < 200 mesh are plotted in Fig. 5. Each point on the graphs represents the average of two or

three specimens estimated at three positions across the surface. Noteworthy is the $< 5\mu$ curve which changes direction toward the origin around 12% quartz. The similarity to the $< 5\mu$ curve derived by binder free preparation is striking and suggests a common denominator in terms of the powder fraction rather than sample preparation.

The deviation from linearity which becomes significant in the 75-100% range of the $< 5\mu$ curve for binder specimens appears to be characteristic of the binder type of preparation. Geiger tube response showed linearity well beyond the discharge rate of 100% samples. The binder free-curve for the same material was linear in that concentration range. The < 200 mesh and the 5μ to 200 mesh curves, linear along their major course, proceed through the origin and confirm theory except above 75% where the influence of slide preparation also become significant. This phenomenon is under investigation and will be reported on in a separate paper. Preliminary study indicates that change in slope is related to fluorite content, for internal standards containing one-fifth fluorite yield curves with significantly greater deviation from linearity.

Reference to the < 200 mesh curve of binder-free samples (Fig. 4) and to the curve for binder type (Fig. 5) indicates that material of this fraction gives the same I_Q/I_f ratios up to 75% whether prepared as binder type or binder free. Results of analyses on settled foundry dusts, shown in Table III, confirm this finding. Though close agreement was obtained by both sample preparation techniques, the tedium and uncertainty of resurfacing that is involved in working with binder-free preparations of < 200 mesh material exclude the method on practical grounds.

Surface uniformity of binder preparations of $< 5\mu$ material was found to be slightly better than that of the binder free type tabulated in Table II. The same small advantage followed on a specimen to specimen comparison where binder type varied from $\pm$ 0.5% quartz at 6% level to $\pm$ 3% at 100% level. This specimen reproducibility indicates that the loss of slope from which the binder curve suffers beyond 75% quartz does not jeopardize analytical accuracy.

Table IV summarizes ratios for < 200 mesh powder prepared by binder technique.

TABLE III.
COMPARISON OF QUARTZ ANALYSIS
BY TWO SPECIMEN PREPARATION TECHNIQUES

Sample Number	Specimen Number	I_Q/I_f at Specimen Position (1)	(2)	(3)	Average	% Quartz*
50-11 B	Binder 1185	0.22	0.23	0.20	0.22	10
"	Binder 1186	0.17	0.21	0.17	0.18	8
"	Binder 1189	0.23	0.15	0.20	0.19	9
"	Binder-Free F 216	0.19	0.42	0.21	Discard	
"	Binder-Free F 217	0.60	0.20	0.22	Discard	
"	Resurfaced F 216	0.18	0.15	0.24	0.19	8
"	Resurfaced F 217	0.17	0.21	0.19	0.19	8
50-11 C	Binder 1187	0.14	0.17	0.14	0.15	6
"	Binder 1188	0.13	0.16	0.15	0.15	6
"	Binder-Free BF 218	0.13	0.12	0.21	0.15	6
"	Binder-Free F 219	0.12	0.12	0.15	0.13	5
"	Resurfaced F 218	0.09	0.12	0.16	0.12	5
"	Resurfaced F 219	0.13	0.12	0.14	0.13	5

*From curves in Figs. 4 and 5.

TABLE IV.
BINDER SPECIMEN UNIFORMITY
< 200 MESH
QUARTZ — CALCITE — FLUORITE

Specimen	% Quartz	I_Q/I_f at Specimen Position (1)	(2)	(3)	Average	Plot
1231	12	0.26	0.23	0.27	0.25	
1235	12	0.28	0.28	0.26	0.27	0.28
1236	12	0.32	0.34	0.31	0.32	
1228	50	1.20	1.22	1.12	1.18	
1229	50	1.14	1.05	1.22	1.14	1.15
1230	50	1.17	1.05	1.15	1.12	
1232	75	1.86	1.73	1.60	1.73	
1233	75	1.50	1.65	1.70	1.62	1.66
1234	75	1.60	1.71	1.55	1.62	
1225	100	2.18	2.05	2.00	2.08	
1226	100	2.00	2.00	1.96	1.99	2.04
1227	100	2.01	2.00	2.12	2.04	

TABLE V.
BINDER SPECIMEN UNIFORMITY
5 MICRON TO 200 MESH
QUARTZ — CALCITE — FLUORITE

Specimen	% Quartz	I_Q/I_f at Specimen Position (1)	(2)	(3)	Average	Plot
1269	12	0.24	0.21	0.28	0.24	
1270	12	0.25	0.25	0.24	0.25	0.24
1271	12	0.27	0.22	0.21	0.23	
1156	50	1.10	1.10	1.00	1.07	
1157	50	1.52	1.63	1.92	*1.69	1.14
1158	50	1.23	1.31	1.06	1.20	
1159	75	1.74	1.78	1.82	1.78	
1160	75	1.70	1.65	1.59	1.65	1.67
1161	75	1.57	1.68	1.52	1.59	
1275	100	2.00	1.87	1.82	1.90	
1276	100	2.16	2.06	2.36	2.19	2.07
1277	100	2.21	2.16	1.99	2.12	

*Discarded—Disuniform

Variation ranged from ± 1.5% quartz at 12% level to ± 3% at 75 and 100% level. The 5μ to 200 mesh size range yielded comparable results as shown in Table V with variation ± 0.5% quartz at 12% and ± 8% at 100% level. It is evident that large particle size material can be satisfactorily analyzed by binder technique.

Some Binder Specimen Characteristics

DURING the course of experiments directed toward establishing the conditions of binder preparation rendering the reproducibility discussed above, observations on variant specimens were made. This type has an important advantage as their characteristics can be examined in more detail than can the packed type. Transillumination by bright light was particularly useful for this purpose.

It was early found that specimens which spread out on the slide beyond a 1¼" x 1" area gave excessively high or low I_Q/I_f values. These resulted when amyl acetate in excess of 0.6 cc. was used to prepare < 200 mesh material. High averages were most common and were associated with high I_Q/I_f values at all three slide positions or with widely different ratios at the three positions.

It can be assumed that such slides were below the critical thickness necessary for maximal diffraction. Slides prepared using less than the specified amounts of amyl acetate tended to be wrinkled when dried and generally would not cover a one square inch area. On transillumination, such slides were frequently found to possess dense centres and crystalline edge. They yielded low I_Q/I_f values. It was found that tilting of slides to spread the ground preparation over the specified one square inch area could lead to gross disuniformity. Excessive tilting tended to leave material set toward one slide edge with the result that a light and dense area division was created. These slides were characterized by high average value with wide variation at the three scanning positions.

The occurrence of disuniform and variant binder specimens is infrequent when prescribed conditions of preparation are followed. As some do occur, however, all specimens are transilluminated and those showing fault may be discarded prior to scanning. Where material is opaque careful examination of the underside of the slide frequently reveals islands, striations or crystallinity which may not be evident on the exposed surface. Further investigation of binder specimen characteristics is being carried out including stratification of specimens containing proportion of extreme specific gravity materials. Fig. 6 shows specimen 1157—50% mixture of 5μ to 200 mesh material—for which ratio from three slide positions was 1.69 (see Table V) in comparison with 1.07 and 1.20 for the

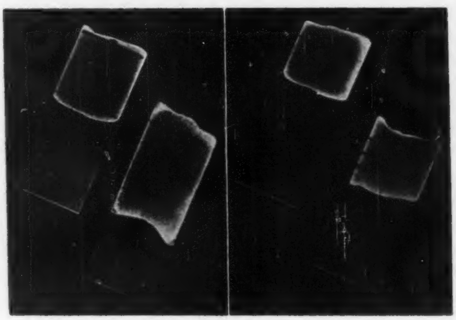

Fig. 6.
Binder specimen uniformity as revealed by transillumination with bright light. Slides 1160 and 871 averaged normal and showed uniformity on transillumination. Number 1157 was excessively tilted and 854 was spread beyond one square inch area. Both averaged high

two other members of the triplicate—numbers 1156 and 1158. This variant was excessively tilted after pouring and set with an uneven concentration of particulate matter. Slide 1160, a normal 75% specimen, shows uniformity on transillumination. In the same figure is slide 857, a 50% specimen of < 200 mesh material which spread beyond the one square inch area on pouring and yielded slide average 15% higher than normal as represented by the uniform adjoining slide 871.

Such findings have emphasized the critical position of specimen preparation in the diffraction analysis field. The gross variation which can occur with small change in conditions of preparation makes this aspect a matter of art as well as science.

Analytical Accuracy

BASICALLY the accuracy of a quartz analysis on a field sample lies in the rationale applied in the initial instance to the raw specimen which is made up for preliminary examination of the analytical case. It announces the presence of components having d values close to or upon the d values for quartz and fluorite. If components exist which diffract at 28.36 degrees on the spectrometer, the employment of fluorite is contra indicated. Recourse may be made to nickel oxide, sodium chloride or other crystallites for use as internal standard; or, alternatively, if low accuracy is acceptable, estimation of the effect of the component on the diffraction of the fluorite internal standard can be made. Should superposition occur close to or upon the 3.33 angstrom line of quartz, recourse may be had to the 4.25 line of quartz, or, as above, accuracy may be sacrificed, the 3.33 line employed for I_0 in the IT ratio and the influence of the superposing compound estimated. The trace of the raw specimen provides some check on the particle size range; narrow base traces reflecting larger size particles, wide base traces reflecting the presence of sub-micron particles.

In the absence of the complications referred to above, the technique is straightforward. A choice of binder or binder-free type of preparation is made largely on the basis of the known particle size; < 200 mesh powders being preferably handled by the binder technique; < 5 micron particles may be handled by either technique. Samples containing known constituents of extreme specific gravity have been found in our laboratory to be best handled by the binder-free method.

It will be appreciated from the calibration data presented that the choice of slide preparation method represents a second pivot on which accuracy of the analysis will depend. If the slide preparations proceed normally, calibration curves provide the index of accuracy. If, on the other hand, preparations do not turn out well, as measured in terms of agreement between multiplicates, additional slides may be prepared and estimated with a view to confirmation, or transillumination may be resorted to for purpose of discarding, or the actual results on the multiplicates may be accepted and a corresponding accuracy, reflected by the difference in results, may be assigned. These considerations which form the third and final factor in accuracy of results, are obviously related to the ultimate purpose for which the quartz findings are intended.

Summary

INSTRUMENTAL variations and errors in estimating background combine with variations in slide surfaces to form the possible error of a single recorder trace on a specimen. Such possible errors are reduced by the process of scanning three slide areas and by duplicating or triplicating sample preparations which has the effect of further increasing the number of surfaces scanned and multiplies recorder experiences. The employment of calibration curves for different particle size bands and fluorite lot numbers, and for binder or binder-free preparations permits deliberate control of the significant difference over which these features rule. Transillumination of binder slides and resurfacing of the binder-free type permit the neutralization of effect of some extreme variations. Careful control of recorder amplitude and damping recognizes that the internal standard technique does not offset an instrumental characteristic affecting low recorder deflections.

The recorder technique, as described in this paper, offers a compromise between accuracy and speed which is entirely accept-

able in the industrial hygiene field. Combined with suitably organized laboratory procedures for sample handling, the recording spectrometer permits the analysis of numbers of samples which by any other method would be beyond the practical possibilities of modern health budgets.

[ACKNOWLEDGMENT: It is desired to acknowledge the technical assistance of J. P. A. Stang.]

Bibliography

1. FRIEDMAN, H.: Geiger Counter Spectrometer for Industrial Research. *Electronics*, 18:132, 1945.

2. KLUG, H. P., ALEXANDER, L., and KUMMER, E.: X-ray Diffraction Analysis of Crystalline Dusts. *J. Indust. Hyg. & Tox.*, 30:166, 1948.

3. KLUG, H. P., ALEXANDER, L., and KUMMER, E.: Quantitative Analysis with the X-ray Spectrometer. *Anal. Chem.*, 20:886, 1948.

4. CLARK, G. L. and REYNOLDS, D. H.: Quantitative Analysis of Mine Dusts—An X-ray Diffraction Method. *Ind. & Eng. Chem. Anal.*, 8:36, 1936.

5. ALEXANDER, L.: Geometrical Factors Affecting the Contours of X-ray Spectrometer Maxima I—Factors Causing Asymmetry. *J. App. Physics*, 19:1068-71, 1948.

6. BIRKS, L. S.: Geiger Counter Technique for X-ray Diffraction Part VI. Detailed Considerations of Experimental Conditions. *U.S. Nav. Res. Lab.*, Rep. H-2517, 1945.

7. MCCREERY, G. L.: Improved Mount for Powdered Specimens Used on the Geiger Counter X-ray Spectrometer. *J. Am. Ceram. Soc.*, 32:141, 1949.

8. BALLARD, J. W., OSHRY, H. I., and SCHRENK, H. H.: Sampling, Mixing, and Grinding Techniques in the Preparation of Samples for Quantitative Analysis by X-ray Diffraction and Spectrographic Methods. *J. Opt. Soc. Am.*, 33:667, 1943.

9. TAYLOR, A.: The Optimum Thickness of Powder Specimens in X-ray Diffraction Work. *Phil. Mag.*, 35:632, 1944.

Announcement

The American Industrial Hygiene Association Quarterly in order to be of greater service to its subscribers is adding a new feature with this issue. Vacancies in the field of industrial hygiene will be listed as received without charge.

A LARGE American industrial concern wishes to add to its present Industrial Hygiene staff an Industrial Hygienist who has had broad experience and training in this field. The position will require considerable traveling and field work, and involves making surveys and reports. A minimum of three years experience in the field is required. Salary commensurate with training and experience.

The Washington Branch of the International Labor Office announces a vacancy in the Industrial Hygiene Division of the International Labor Office at present located in Geneva. The position is that of Member of Section, Industrial Hygiene Division. Applicants must be United States citizens between the ages of 27 and 35. University education with a degree of Doctor of Medicine is required. Applicant must have ability to write well in English and a good knowledge of French. Additional languages will be considered. Applicant must have a thorough knowledge of industrial medicine, both practical and theoretical. The salary scale extends from $4,410 to $7,850. By promotion, access may be gained to a higher category, whose scale extends from $7,850 to $9,700. The duties involve collection and classification of documentation in respect to occupational health, and especially medical rehabilitation, drafting of notes on the above questions for office publications, assistance in preparation of reports for conferences and committees, furnishing technical information and advice on occupational health.

The initial salary for the present appointment will be fixed at $5,000 unless age, experience and qualifications of the successful candidate justify a higher commencing salary. Applicants should apply to the Washington Branch of the I.L.O., 1825 Jefferson Place, Washington 6, D.C., giving full information on the required qualifications as listed above. Applications should be filed before January 31, 1951.

Several well-trained Industrial Hygienists available. This is to call attention to prospective employers of the fact that a few well-trained graduates in June, 1950 with Masters Degrees in Public Health are available for employment in the field of Industrial Hygiene. Although they lack actual experience, their training is such that they would make desirable additions to an Industrial Hygiene staff either in Industry or Government.

For further information relative to the first position listed above and relative to the available personnel in Industrial Hygiene, please contact Frederick W. Sands, c/o United States Rubber Company, 1230 Avenue of the Americas, New York 20, New York.

The Placement Committee has several other openings in addition to the above, for which applications are invited.

Industrial Toxicological Investigation

HENRY F. SMYTH, JR., and CHARLES P. CARPENTER,
Mellon Institute,
Pittsburgh, Pennsylvania

CERTAIN DIVISIONS of the Union Carbide and Carbon Corporation are large producers of a wide variety of chemicals, few of which are sold directly to the consuming public. In 1937 it became apparent that toxicological information required by the divisions of U.C.C. could no longer be satisfactorily supplied by temporary arrangements with educational institutions and consultants. Permanent facilities were necessary. Close coordination of toxicological studies with other Corporation activities was required to assure protection of the health of workmen and to guide development of markets for chemicals being originated and produced. It was judged that one of the functions of the toxicologists would be criticism. An organization apart from the Corporation would possess an impartiality and prestige that would increase the weight of its opinions. Since such an arrangement would require a coordinator within the Corporation, the following solution was elaborated. The Industrial Toxicology Department was established within the Corporation, to function as a clearing house for toxicological and medical information and opinion. Experimental facilities were provided at Mellon Institute under the name of the Chemical Hygiene Fellowship. It is with the latter that we are at present concerned.

Scope of Fellowship Activities

BY MEANS of animal experiment the Chemical Hygiene Fellowship obtains information on any health hazards of the materials, processes and products of the units of the Corporation, emphasizing those of the Carbide and Carbon Chemicals Division. It considers hazards of production, shipping and application. Its studies are aimed at investigating every chemical of interest to the Corporation in order to obtain preliminary information upon potential hazards before samples are furnished to outsiders. As new chemicals progress through successive stages of development, more advanced data are obtained upon promising specimens to determine the safety of proposed applications, or the unsuitability of the compounds because of associated hazards to health.

In a highly competitive industry there must be little delay in the evaluation of new applications of chemicals while laborious toxicological studies are being performed. Facilities must be adequate to undertake new investigations upon short notice. For efficiency and maintenance of morale there must be a sufficient amount of non-pressing work to occupy the staff at all times. The Fellowship's standby work, which can be set aside when urgent problems arise, is found in two areas. Long-range investigations upon methods for the detection of injury and upon physiological mechanisms are stimulating to those trained in research but who must work upon routine problems by standardized methods much of the time. Preliminary study of all new chemicals under investigation by other laboratories of the Corporation is undertaken before applications are foreseen or even before manufacturing processes are developed. Although this work can be put aside in periods of pressure, it is quite important. Such studies result in the accumulation of data from which there can usually be formed on short notice tentative judgments of the safety of proposed applications.

Avenues of Information

IT IS OUR AIM to obtain preliminary information upon every compound being studied by research and development laboratories of the Corporation, and to have on file tentative information upon each chemical in advance of a request. Such a goal cannot even be approximated without reliable information upon the activities of other laboratories. It has been found that obtaining knowledge of the direction of their work is not a simple straight-forward operation, and several routes for its collection have had to be established.

Practically continuous contact between the Industrial Toxicology Department and various sales groups in the Corporation's main offices keeps that Department informed of new applications being considered for specific chemicals and of new products being offered to the trade. Where questions of toxicity are involved, reports of call from salesmen in the field pass through that office. Furthermore every opinion on toxicity or health hazards directed to a customer or to any other interested party either originates in that office or is cleared there before being mailed.

Participation of the Department in the Labeling Committee, which is continuously concerned with laying out precautionary labels for new products, is a further source of contact. The observations and questions of industrial physicians in the various Corporation plants are sent to that office. All these sources give the Industrial Toxicology Department information upon the Corporation's need for new toxicological data, and this information is in turn transferred to the Chemical Hygiene Fellowship, which must then set about obtaining the data.

If we depended solely upon information reaching the Industrial Toxicology Department there would be too much delay in starting work on many chemicals. Personal communication with others at Mellon Institute who are developing new applications is a fertile source of information. Direct contact is maintained by mail and telephone with several research and development laboratories, and occasional visits to these groups furnish further help.

What might be considered a clean-up step is the policy of the shipping department at the largest plant. It will ship nothing until the Fellowship has given an opinion upon proper labeling to meet I.C.C. regulations on classification of poisons.

The several formal and informal contacts enumerated allow the Fellowship to undertake preliminary toxicity studies upon new chemicals very early in the course of their development. As a result, in many instances tentative information is at hand before a formal request for advanced work reaches us.

Staff

THE FELLOWSHIP staff numbers twenty-five. It is small enough to allow a loose organization, adapted to individual attributes and the requirements of the work. The Administrative Fellow is analogous to a research director. He maintains the majority of the contacts of the Fellowship with units of the Corporation and also much of the committee service and public speaking which are important parts of the public relations of a professional group.

The Advisory Fellow is a physician who has specialized experience in physiology and pathology. One Senior Fellow is a biochemist who is assisted by two technically trained helpers. The other Senior Fellow is responsible for all animal treatment except that which is solely for the purpose of elucidating biochemical or physiological phenomena. His technical assistants are practically interchangeable among the various types of small animal treatment. They are loosely divided among four activities: single doses to rats, mice or guinea pigs; repeated doses to small animals; work with rabbits, such as irritation, eye injury and skin absorption tests; inhalation tests. The Fellow who supervises the rabbit tests is also a statistician for the Fellowship. Studies on the larger laboratory animals are done by the two Senior Fellows together with the more experienced assistants.

These technically trained persons are aided by ten workers who prepare histological specimens, make literature surveys, furnish secretarial services, and care for the equipment and animals. Many auxiliary services are available from Mellon Institute, the most indispensable of which are the technical library, purchasing and accounting departments, chemical and apparatus stock room, machine shop, glassblower, duplicating service and messenger.

A specialist in animal pathology is retained to interpret the histological preparations resulting from the studies. Tests for human dermal sensitizing ability are conducted by a consultant.

Figure 1 is a chart showing the organization of the Fellowship. It may serve to clarify the relationships and divisions of the Fellowship staff that have been outlined.

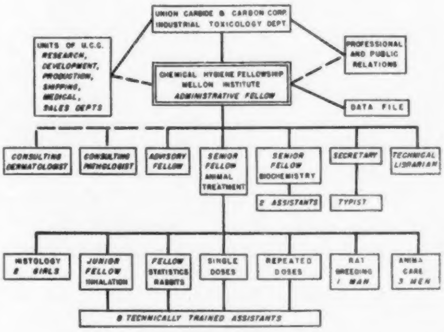

Fig. 1.
Organization of the Chemical Hygiene Fellowship of Mellon Institute

Facilities

THE FELLOWSHIP occupies one floor of about 7000 square feet in a laboratory building. The experimental animals consisting of mice, rats, guinea pigs, rabbits and dogs, are housed in seven rooms and for the most part are treated in the same space. Two rooms are devoted to inhalation studies, one to histological preparation, two to chemical analysis and biochemical studies, and one to radioisotope technique. One room is a technical library and one a secretarial office. There are four staff offices, one locker room and a sample storage room. The corridor is used for additional work and storage.

About 1000 rats are produced within the Fellowship per month, and 200 rabbits are purchased in the same period. Other species are used more irregularly in smaller numbers. There are 1200 cages of various sizes and the animal population under observation approaches 5000.

Planning and Follow-Up

ALL OUR PRELIMINARY work, ordinarily called Range-Finding Testing, and much of the more detailed study we refer to as advanced work are done by methods standardized by the Fellowship for its own use. Because of this standardization, we feel that we can place reliance in quantitative comparisons of results gathered over a period of many years.

When information or a request prompts us to start preliminary studies, as many data as possible are collected upon physical properties and probable useful applications. We attempt to foresee the most likely type of human contact with the chemical. The toxicological literature is routinely searched, but upon new chemicals it is seldom productive. The Administrative Fellow then decides what standardized tests should be performed: single or repeated oral doses, skin penetration, inhalation, skin contact, eye injury, etc. He estimates the cost and notifies all specially interested persons that the work is being undertaken.

When advanced work is requested the application is usually definitely specified, pertinent laws and regulations which must be met are known, and planning of quantitative phases of the study is simpler; however, the procedure is essentially the same. Biochemical and physiological phases of advanced work cannot be standardized and are not planned with the detail which is possible in quantitative toxicology.

Every study is entered in a follow-up file of Kardex cards. The tests to be performed are shown on the visible edge and colored signals are used to record the progress of each test. As an operation is completed the results are entered on the card, which already bears notations of physical properties and other pertinent information. Inspection of this file at any time will yield all information thus far accumulated on a chemical and will allow prediction of the date on which the study will be finished.

Reports and Publication

UPON THE completion of each study a report is prepared and mimeographed. Details of all observations are tabulated, presented graphically when feasible, and summarized. A feature of reports upon new chemicals is the description of hazards to be expected in production. These are given in the form of comparisons with the hazards known to be associated with more familiar structurally related compounds. To those already dealing with the familiar materials, the comparisons indicate the nature and the stringency of precautions required to protect workmen who will handle the new chemicals.

From time to time review reports consider broad groups of chemicals, or they summarize all tests for one particular haz-

ard. Rating systems for degree of hazard are built up on the basis of review reports. They group together into one activity grade all chemicals whose hazard or toxicity in one particular type of exposure is for practical purposes identical in a quantitative sense. Fifteen rating systems have been outlined, each including compounds that are devoid of practical hazard, compounds among the most hazardous we have studied and intermediate materials. Five, ten or twenty activity grades are recognized for specific hazards, the number depending upon the sensitivity and precision of the experimental methods employed. In general, a particular grade indicates a hazard or toxicity about twice as great as the next lower numbered grade.

Furthermore, monthly progress reports list all projects under way and give data upon studies too brief to justify special reports. An annual report surveys work of the year, discusses changes in facilities and personnel, and outlines plans for the future.

In order to facilitate reference to any of the 1300 reports we have issued, serial numbers are assigned to the documents. The first part of the number signifies the year in order that the age of data may be evident at a glance.

Each report is mailed to 15 persons in medical, research, production and sales departments of U.C.C. divisions. Additional copies are sent to other persons who may have a special interest in the particular compound, and at times they are given to customers of U.C.C. or to Federal agencies. Most persons on the regular mailing list circulate the reports among their associates, and it is safe to say that each document passes over 50 desks.

Experience shows that the majority of the reports are not permanently filed by the recipients. Accordingly inquiries about past work must be directed by necessity either to the Fellowship or to the Industrial Toxicology Department of U.C.C. From either place replies may include new information which would not have been available had old reports been consulted. It may appear wasteful to send out for only temporary use voluminous reports replete with tables of detailed observations. We have found by experience, however, that our routine office work is less when we send the same report to everyone than when we prepare one page summaries for part of the mailing list. The present bulky reports bear the summary on the first page, and those who want no details need read no further.

In addition to one report on the average of every three days, paths of information and opinion to U.C.C. personnel include frequent personal contacts with all departments and a steady stream of letters of inquiry. Most of the letters are concerned with the safety of applications of chemicals and rightly are directed to the Industrial Toxicology Department at the main offices. Here contact in person and by telephone is very close between that Department and the sales and production personnel.

Communications to professional colleagues are partly in answer to letters or telephone calls of inquiry and partly by publications in technical journals. It is expected that every fact the Fellowship establishes will be published, although in a few instances commercial secrecy delays release for a time. Up to this date 40 articles either have appeared or are in press, being chiefly communications of new facts about specific chemicals.

A moderate number of addresses are delivered to professional and lay groups. These talks seldom discuss the toxicity or hazards of specific chemicals. They outline the need for toxicological studies, methods for conducting studies, and general considerations of health hazards from chemicals. In order to facilitate public addresses a brief movie film has been prepared to illustrate some of the techniques for treating and observing small animals. Purposely no recorded narrative is embodied in the film in order that spontaneous running comment from the speaker may interest and enliven the audiences.

Data Files

THE FELLOWSHIP has never had the services of a person specifically trained in filing procedures, but it is doubtful if experience in conventional office filing would have met our needs. Several difficulties have arisen which have led to the present arrangement of data files. Twice in the early years, work on a particular chemical

was repeated because we did not remember it had been done before. Several times we have been confused by a change in the name given to a compound when it was shifted from research to production departments. At least half of the opinions expressed by the Fellowship are given during telephone conversations; consequently all our data must be at our finger's tip. Once we have reported on the study of a chemical, most of the opinions upon its proper handling and application originate in the Industrial Toxicology Department of U.C.C., although plant medical departments and research groups have frequent need to obtain brief summaries of the toxicity of compounds we have tested.

After seven years of work the condition of our files was surveyed, the needs they must meet were outlined and a major revision was made. This undertaking was completed in two years, a task requiring half the time of the Administrative Fellow in the interval. If the situation had been foreseen when we started in 1937, that time could have been saved. A major responsibility of the Administrative Fellow is now keeping the data files up-to-date, and this attention requires about three days a month for the typist and himself. There are 27 files of data, observations, slides and the like, material which must be kept separate because of their physical nature or subject matter.

There are three data files, the duplication being judged necessary because of the different needs of the people who will use them. They are brought up-to-date during the preparation of each monthly report.

The Kardex file is the key to all other files and it rests by the Administrative Fellow's telephone. Its 2000 headings include one card for each grade of each chemical we have tested. On the visible edge of each card is a line of 31 numbers representing 22 standardized test procedures and nine categories of other information. Boxes drawn around numbers indicate what particular tests have been performed. By code it is shown in what detail the test was conducted and whether the results were published. Each card is 8 x 9 inches, folded once. On the outside surface there appears the chemical structure, synonymous names, sample number and some physical properties. Inside on 31 numbered lines corresponding to the numbers on the visible edge, there appear one-line statements of the results of every test done on the compound. The statements are in a condensed form not intelligible to outsiders. When the test is one of the standardized procedures there appears also a symbol giving the activity grade in the corresponding rating system by which we scale response. Each line bears a reference to one or more of 10 satellite files of data, such as notebooks, autopsy sheets, pathology interpretations, slide boxes, photographs, reports, and publications.

The Kardex cards are filed alphabetically by currently employed chemical names with cross references for trade names. In addition, on the visible edge appears a structural number which will be discussed in the next paragraph.

All our quantitative data are coded on hand-sorting punch cards (Keysort) and it is hoped that qualitative data can be added at a later date. Each of the 1800 cards bears the chemical name typewritten thereon. In the double row of holes on all four edges of the card are punched perforations indicating the structural number, each test performed on the compound, and the results by activity grades in 13 of the standardized tests. The cards allow rapid sorting according to hazard in different types of exposures and contacts, as well as correlation between hazards. The structural number is assigned to show each physiologically functional group or element in a chemical and it allows sorting for any group or combination of groups. The number is not unique for a chemical, but it divides a wide range of compounds into small groups of structurally similar molecules. There is maintained a file of structural numbers already assigned, and therein we can locate a chemical whose name has been changed since we first examined it.

Neither file is available to those not working on our Fellowship, nor would these files be useful to anyone else because of the abbreviations, codes and conventions employed. To meet the needs of other groups in U.C.C. data files are maintained in eight locations. The cards are pre-

pared by typing with carbon paper backing on tracing paper cut to 5 x 8 inches and the master sheets are duplicated by the Ozalid process. Cards are filed alphabetically with cross references by trade names. Entries are brief statements without abbreviations, giving all findings with references to reports where discussion or further details appear. Each card is numbered serially and dated to facilitate its removal when a revision is furnished. The eight copies of this data file are in the offices of medical personnel and the research libraries, where presumably the users will be cautious if they have insufficient background to interpret the data. Others obtain opinions with or without data from the Industrial Toxicology Department or from the Fellowship.

Cost Accounting

THE FELLOWSHIP does not operate upon a fixed budget because its activities are governed almost entirely by fluctuating demands for service from various U.C.C. units. Nevertheless it must estimate the cost of each study, and it must divide its expenditures equitably among the various divisions of U.C.C. on whose problems it works.

At the close of each fiscal year the total expenditures of the Fellowship are distributed among all the productive activities in such a way that there results an estimated cost for each unit operation. Examples of unit operations are: mimeographing one page of report, feeding one rat by stomach tube, one rat on a controlled diet for one day, preparing a slide of one animal organ, one day of work for a biochemist, and the like. The costs of long-range research, of errors in judgment in planning studies, of correspondence and of professional activities and public relations work are considered as part of overhead and are automatically divided among the productive activities. In those instances where unit costs have been compared with those of other toxicologists, reasonably close correspondence has been observed. The cost of one project is the sum of the costs of the unit operations performed.

Supervision

IN POLICY matters the Fellowship is responsible to an Assistant Director of Mellon Institute. By a strict interpretation of the situation the Fellowship has no direct organizational connection with the Union Carbide and Carbon Corporation or with the different units. The Corporation contracts with Mellon Institute to maintain the Fellowship, the costs of which are paid by the Corporation to the Institute.

In scientific and professional matters the Fellowship is guided partly by an Assistant Director of Mellon Institute and partly by the head of the Industrial Toxicology Department of U.C.C. The contract with the Institute is signed by a vice-president of the Carbide and Carbon Chemicals Division of U.C.C., and it is his responsibility to supervise the Fellowship in regard to expenditures and to determine the need for all major studies undertaken.

The growth of the Fellowship from a very modest beginning in 1937 can be accounted for entirely by the patience of U.C.C. personnel while they and we were learning how to work together. Now each party has learned something of the needs of the other and mutual education will undoubtedly continue, leading to more efficient and successful operation.

The Control of Cerain Health Hazards Encountered in Underground Metal Mines

EDWARD C. J. URBAN,
Industrial Hygiene Engineer,
Saranac Laboratory
The Edward L. Trudeau Foundation
Saranac Lake, New York

UNDOUBTEDLY the principal hazard to health of common concern in metal mining has been related to the inhalation of dusts containing crystalline free silica, chiefly in the form of quartz. Of somewhat lesser importance has been the influence of such other hazards as the nature of the specific ores extracted, excessive concentrations of gases and smoke resulting from blasting, air deficient in oxygen, gaseous products of the associated rock formations, excessive levels of carbon dioxide, methane, temperature and humidity.

Experience has demonstrated that in open pit mines exposed to outside air conditions and weather, where wet drilling and other reasonable dust suppression practices were applied, these hazards at best were only small. The following discussion, therefore, will be confined to underground mines. It will present certain factors of interest which the Saranac Laboratory has experienced in its silicosis control investigations and efforts in more than two-score hematite, magnetite, copper, lead and zinc mines located throughout certain sections of this country.

Essential requirements for insuring safe working atmospheres in underground metal mines are: an adequate volume of clean outside air to provide the mine with good general ventilation; planned systems of air courses which effectively distribute this air supply to the areas of mine activity; provisions for removing smoke and exhaust air from the mine with exposure to the fewest men and auxiliary systems which mechanically deliver ventilation to the remote or dead end workplaces. These fundamentals are of equal importance to the use of water to allay dust, regulated blasting, the use of respirators, education of the men in good dust-prevention practices and the frequent inspection and analysis of working environments.

Today, labor has become increasingly concerned with working conditions. Accumulations of blasting smoke in mining areas has meant avoidable delays in production and a hazard to safety. The U.S. Bureau of Mines reported six fatalities which occurred during the past five years in metal mines and tunnelling developments as the result of asphyxiation from blasting gases and oxygen deficient air. Other fatal accidents probably have occurred in which poor air was a primary cause. It is not unusual for sulfur-bearing slates to burn underground, following exposure to air and requiring sections of a mine to be completely sealed off for years. Methane has on occasion been found in the de-watering of old mines. Carbon dioxide and heat resulting from the decomposition of mine timber and heat from progressively higher rock temperatures encountered with deeper mining have produced uncomfortable working conditions.

An industrial hygiene program for metal mines to be effective must be designed and applied to give consideration to and establish good control of all these factors.

Characteristics of Mines

THE MINES observed varied in size from the smallest which employed about 20 men underground per shift to the largest which worked 290 men per shift. The depth of mining ranged from 300 to 3500 feet below surface.

The ore deposits in the largest group of mines were of sedimentary origin which had later been altered. They occurred as massive bodies of merchantable ore concentrated from the surrounding low-grade formations along faults and igneous intrusive dikes. In a second group of mines the ore was of probable igneous origin and

Presented at the Eleventh Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Chicago, Illinois, April 24-28, 1950.

was present in heavy irregular veins which graded into the enclosing rocks. In a third group of mines the deposits were as unaltered sediments. They occurred as beds or layers of fairly regular thicknesses separated and enclosed by other layers of sedimentary rock.

The nature of the rocks associated with these ore bodies varied in mineralogical composition dependent upon their geographical location and manner of deposition. In the Lake Superior Region for example, the Goodrich quartzites, Negaunee Iron formation and Siamo slate were predominant on the Marquette Range. Graywacke, gray and black Footwall Slate, Iron formation and graphitic Black Slate occurred on the Menominee Range. Those common to the Gogebic were the Quartzites and Quartz slates, the Ironwood Iron formation with its cherty members and the inter-bedded Tyler Slates.

In the Adirondack district the gabbros, granites, syenites and gneisses were predominant with large masses of included pegmatites. Shale and sandstone were common to the Clinton formation, in Alabama.

Similarly, the free silica contents varied with the specific rocks. They ranged from about 6% free silica in the syenites to more than 60% in the quartzites.

General Mine Ventilation

A NUMBER of different methods of mine ventilation were observed during the past more than ten years of study. Ventilation by natural means alone has proven to be generally unsatisfactory. The wide variation between low air volumes during the summer months and the higher volumes during the winter months led to unpredictable conditions that were difficult to control. Currently, all of the mines which had been observed with but three exceptions are provided with mechanical ventilation. These three enterprises utilized a system of open-stope mining with supporting pillars in ore deposits of a massive continous vein-type. They are situated in the Adirondack Region where the cold winter months allowed a method of natural mine air conditioning and ventilation to be employed similar to that first developed in Canada. By this method, surface water was allowed to accumulate in the old stoped-out mine areas close to surface and through which the mine air supply was admitted. During winter the cold outside air was heated several degrees in temperature as it passed over and turned the stored water into ice. At atmospheric pressure, ice melted at 32°F. and the latent heat 144 B.T.U. per pound. In summer the reverse occurred as the warm outside air was cooled by contact with the melting ice. Relatively constant temperature differentials were maintained the year-round between the intake air sections and the mine workings at the lower elevations. Continual air supplies of large volume were produced and the temperatures in the mine workings ranged from 60 to 70 degrees Fahrenheit.

This simple and effective method of mine ventilation eleminated the costly need of preheating mine air supplies in winter and is one which can be utilized to good purpose by other similarly situated mines.

The need for providing mines with adequate supplies of outside air for *general mine ventilation* has been recognized for many years. However, workable standards of accepted good practice or definitions of adequate mine volumes are still lacking. Many of our state codes or regulations, for example, suggest the provision of as little as 100 or 200 cubic feet of air per minute per man. These requirements are equalled and often exceeded by the air discharged from modern pneumatic drills and shovel loading equipment used in mining.

During 1943, twenty-five mechanically ventilated underground iron-ore mines in the Lake Superior District was surveyed to determine the efficiency of their ventilation. Table I presents a classification of these mines by ventilation conditions, number of men employed and the type of mining. The term "Ventilation Index" represents an evaluation of conditions in each mine. Ventilation in those rated as D was judged as being generally inadequate. In the C, B, and A mines ventilation was increasingly more effective.

Employment data were based upon the largest daily shift. The ratio of the number of miners on the day shift to the total men underground on the same shift

TABLE I.
CLASSIFICATION OF 25 MECHANICALLY VENTILATED UNDERGROUND IRON-ORE MINES
By Number Men Employed and Ventilation Conditions in 1943

		Range		Average		
Type of Mining	Number Mines	Number of Men per Underground Shift	Total Mine Volume, Cu. Ft. per Minute	Cu.Ft. per Min. per Miner per Shift	Cu. Ft. per Min. per Man per Underground Shift	Ventilation Index
	3	30—55	25,000—40,000	1,200	850	A
Sublevel	3	30—60	20,000—40,000	1,000	650	B
Stope	2	40—60	20,000—25,000	750	450	C
	2	50—60	15,000—20,000	500	300	D
	3	60—250	45,000—200,000	1,500	800	A
Sublevel	1	90	55,000	1,000	600	B
Cave	2	65—100	20,000—40,000	650	350	C
	1	65	Less than 20,000	550	250	D
Radial	2	75—95	50,000—60,000	1,250	700	A
top slice	1	135	65,000	1,000	500	B
	2	90—160	35,000—60,000	700	400	C
	3	60—200	15,000—50,000	500	250	D

for all these mines ranged from 0.45 to 0.63. In the majority of mines this ratio approximated the average of 0.54.

A review of Table I indicates that the number of men underground on the largest daily shift can be used as a suitable measure of the volume of air required for such iron-ore mines. *It can further be concluded that the minimum requirement for adequate general ventilation is an air supply yielding 500 cu. ft. of air per minute per man underground.* It is important to note, however, that to effect better ventilation control this quantity must be supplemented in accordance with the type of mining employed. In the radial top-slice method, for example, the mining was done in small tunnel-like sub drifts which required moderate volumes of ventilation. As the size of the mining place increased, correspondingly larger volumes of air were necessary. The stope systems of mining required the largest ventilation volumes.

Twenty-four mines in this same area were re-examined in 1949. Similar employment and ventilation data were obtained and are presented in Table II. Changes in mining methods had occurred during the six-year interval. Relatively few mines had retained the radial top-slice system. Of most importance, mine operators had given added attention to providing increased ventilation volumes. Where in 1943, 40% of the mines had ventilation supplies of 400 cu.ft. per man and less, in 1949 all mines had in excess of this amount.

Similar observations conducted in other metal mines throughout this country have substantiated the requirement of 500 cubic feet per minute per man underground as a practicable minimum and that this value must necessarily be raised for the large open stope mine or in mines where heat is a factor.

TABLE II.
CLASSIFICATION OF 24 MECHANICALLY VENTILATED UNDERGROUND IRON-ORE MINES OF TABLE I GROUP
By Number of Men Employed and Ventilation Conditions in 1949

		Range and Median Values of Each Group				
Type of Mining	Number Mines	Number of Men per Underground Shift (1)	Total Mine Volume, Cu. Ft. per Minute	Cu. Ft. per Min per Miner per Shift	Cu. Ft. per Min. per Man per Underground Shift	No. Miners / Men Underground (1)
Sublevel	11	35—286	17,000—130,000	800—2,400	400—1,100	.42—.79
Stope		62	40,000	1,200	650	.53
Sublevel	13	20—230	18,000—200,000	830—3,140	400—1,750	.38—.72
Cave		105	60,000	1,000	580	.57

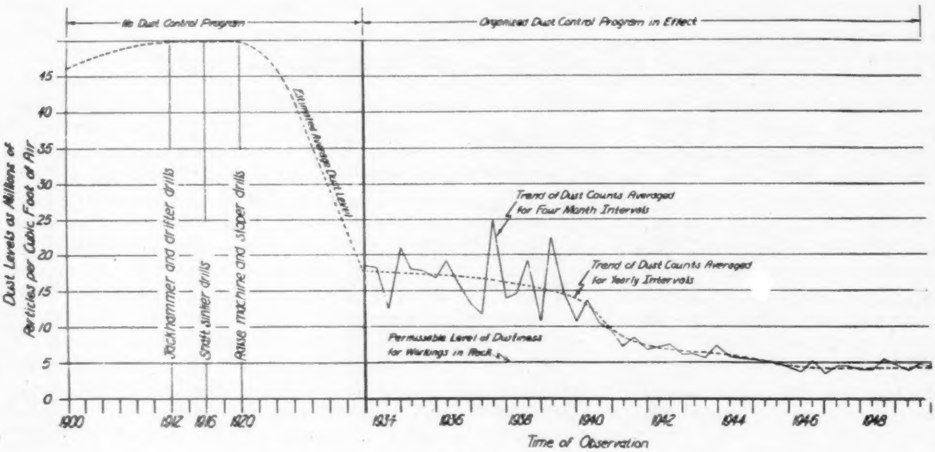

Fig. 1.

Ventilation of Main Drift Developments

IN DEVELOPMENT workings the common practice was to supply the areas with a sufficient volume of clean air to dilute the dust generated by the mining operations and render the resulting air conditions innocuous. Frequent tests have indicated that when supplemented by wet drilling and the copious use of water on the sides and muck pile during loading, *a supply of not less than 2,000 cubic feet per minute of fresh air to the face of an average eight by ten foot drift was sufficient to reduce dust concentrations in most instances to about five millions of particles per cubic foot of air.* The few exceptions experienced, were in workings in rocks of a very fine-grained character as sandstone and shale.

In drifts of larger cross-section the quantity of air supply was calculated to produce a velocity of air flow of about 30 feet, per minute across the drift area. In such instances a delivery of 3,000 cubic feet per minute was the minimum. These ventilation rates were suggested for all common drifting operations irrespective of the free silica content of the rock or ore. It will be noted that such rates are somewhat less than those used in large-diameter tunnel work where air flows equivalent to velocities of 40 or 50 feet per minute have been reported.

Auxiliary ventilation systems for development mining were of two general types. The most common plan was to place the fan unit in a fresh air course and force the air into the working area through sheet metal or spiral-weld pipe. The pipe discharge outlet was maintained within 60 to 90 feet of the working face. Reversible fan arrangements have been employed only to a limited extent. The disadvantages of this method are that the system is limited to the use of a single fan. The reversing dampers must be located close to the unit at a point where excessive resistance and air leakage are developed. Most important, during the exhaust cycle the inside pipe surfaces become coated with dust which is then blown back into the work area as the fan is reversed. The method proving most satisfactory has been a main exhaust system supplemented by a blower unit.

The exhaust fan and piping is installed with the suction inlet in the mining area located usually about 200 feet back from the mining activity. A smaller pressure-fan unit attached to about 200 feet of ventubing is placed on the opposite side of the drift to ventilate the working face. The blowing fan is kept on the fresh air side of the suction unit. This method requires additional equipment but it has the important advantage that the blasting smoke and dust created by the mining operations is exhausted directly from the

work area. The major part of the drift development is kept entirely in fresh air. General work can go on after blasting while the smoke is being cleared from the face.

The effectiveness of these current dust control procedures is illustrated and compared to the results of former methods in Fig. 1. In 1934 a large group of underground iron-ore mines established a dust control program with the aid of the Saranac Laboratory. Dust counts obtained in main drift development working in *rock* in 12 mines during the period from 1934 to 1949 are shown on the right side of the chart. These particular mines were chosen only because records of these data were available. The magnitude of the dust levels as millions of particles per cubic foot of air are plotted as ordinates. The time of observation is along the abscissa. Dust counts averaged for four-month intervals are shown as the irregular solid line. The broken line indicates the trend of the same counts averaged for yearly intervals.

The program in 1934 initiated wet drilling as a requisite. Spraying the workplaces and muckpiles with water during loading, the wearing of air-line respirators, regulated blasting and moderate ventilation control were practiced. These procedures continued with some improvement until about 1939. Increased need for ore at this time demanded accelerated production rates. Ventilation methods were improved and volumes of air supply throughout the mines substantially raised.

The result was a sharp decrease in dust levels as shown by the broken line on the chart from about 15 millions of particles per cubic foot to about seven millions in 1941. Continued improvements in ventilation further decreased dust levels to where they currently meet the permissible level of 5 m.p.p. cu. ft. which had been set for developments *in rock*.

We have extended the left side of this chart to approximate the dust levels which probably existed in this type of work during the period from 1900 to 1934.

The first hammer-type drills equipped with hollow steel rods for drifting work were introduced into the mines of this group in 1912. The drilling was done dry. Shaft sinkers and stoper drills followed in the next eight years. We were advised by local mining men that drilling from 1900 to 1920 was done dry. From then until 1934 the use of water for drilling was possible, but as the suppression of dust was of secondary importance the value of water as a dust allaying device undoubtedly was only partly exploited.

Dust level trends of this type have been observed in other mines. Pneumatic drilling equipment was introduced in different mining sections of this country at about the times shown on the chart. Average dust levels for a period of several years during the early days of drilling were probably not less than 50 million particles per cubic foot. Dustiness was decreased rapidly by the use of wet drilling, then correspondingly lowered as the result of improvements in other control methods.

A further important fact revealed by this chart is an estimate of the possible dust exposure experience of men who have worked in mining as a major occupation for periods of 20 years or longer. The chest or respiratory conditions of many of these men undoubtedly have been influenced by the heavy dust exposures encountered during their early days of work. The essential problem for the industrial hygienist to decide when evaluating the effectiveness of current environmental conditions or control practices, is whether the chest changes in these older men are due to present conditions of work or are progressions of past influences.

Summary

IN THE foregoing presentation factors were discussed which we believe are significant in the control of certain hazards to health associated with underground metal mining. Essential functions of the methods outlined are to prevent the development of new cases of dust disease and to protect old workers who have already acquired some dust reaction resulting from previous exposure, from further progression of their condition.

Current ventilation standards derived from long experience in a number of metal mines have been presented. Their purpose is to aid adequate suppression of dusts and insure efficient general mine ventilation.

The dust level trends reviewed do not represent the findings from any one mine, but are the composite data of several different enterprises.

Stack Gas Cleaning

MELVIN W. FIRST, Sc.D.,
Research Associate,
Harvard School of Public Health,
Boston, Massachusetts

THE SUBJECT of this paper will be that phase of gas cleaning which is concerned with the elimination of particulates from stack effluents.

Drinker and Hatch[1] stated the dilemma inherent in air cleaning devices in the following terms: "The removal of dust from air is made difficult by the fact that a suspension of fine dust dispersed in air constitutes a stable system which requires energy for its destruction. The necessary amount of energy increases with decreasing particle size. In their desire to develop so-called low-resistance cleaning devices, many designers have lost sight of this fact and, as a result, have sacrificed efficiency of operation for lower power consumption." These authors might, perhaps, have added a further caution to the effect that in their desire to develop the ultimate in dust removal, many designers have lost sight of basic principles and practices developed over a period of many years and have sacrificed economy and sound engineering for results which have not justified the means.

Removal of particulate material has been accomplished principally by application of the following physical forces and methods: (1) Inertial forces, (2) Filtration, (3) Wet Scrubbing, and (4) Electrostatic forces. This does not exhaust the available methods by which dust may be separated from an aerosol. Other methods, such as thermal precipitation, are known to be effective, but as no practical ways of applying them to large scale operations have been discovered they will not be discussed. The gas cleaning methods just listed will be reviewed with reference to specific devices, and the aerosols for which each of these devices is most effective will be indicated.

A Contribution from the Air Cleaning Laboratory of the Harvard School of Public Health, operating under Contract Number AT(30-1)841 with the U.S. Atomic Energy Commission. The opinions expressed here are those of the author and do not necessarily reflect the views of the Atomic Energy Commission.

Particle Conditioning

MANY SIMPLE devices give excellent results for particles greater than 5 to 10 microns in size but are ineffective for the finest dusts and mists. Considerable effort has been applied to the investigation of methods for increasing the effective size of fine particles. This has been termed "particle conditioning." The obvious advantage to be gained by particle conditioning is effective use of cheap, less efficient types of air cleaners for the removal of very fine particles. Inasmuch as particle conditioning techniques often require expensive equipment and large expenditures of energy, the net result may be an actual increase in complexity, cost and energy requirements for the system as a whole over what would be required by a more efficient collection method without the use of particle conditioning. It is desirable that particle conditioning and particle collection be clearly differentiated.

Particle size may be increased by spontaneous and induced agglomeration, a process whereby two or more particles, not necessarily of the same material, make physical contact and stick together. The many factors influencing the rate and extent of aggregation of aerosols are discussed in detail in publications by Drinker and Hatch,[1] Whytlaw-Gray and Patterson,[2] Gibbs[3] and others. Their findings indicate that the following are important:

I. Particle Characteristics: (a) size, (b) shape, (c) specific gravity, (d) surface absorptive properties, (e) chemical composition, and (f) electrostatic charge.

II. Aerosol Characteristics: (a) Concentration (number and mass) of the particulate material (loading), and (b) Temperature, pressure and viscosity of the gas.

III. Characteristics of the Agglomerating Forces Applied to the Aerosol: (a) agitation: (1) mechanical, (2) thermal, (3) sonic, (4) gravitational, and (b) electrostatic charge.

Agglomeration of most metal fumes occurs spontaneously and with great rapidity. Freshly formed zinc fume, composed of particles less than a few tenths microns, exhibits vigorous Brownian Motion and collisions are frequent, especially if the air is sufficiently turbulent to produce some mixing. The initial rapid rate of agglomeration falls off due to decrease in number of particles and to cessation of Brownian Motion as the size of agglomerates increases. At this point, gravitational settling becomes effective and considerable fume may become separated from the aerosol. Silverman[4] has observed during experiments involving the continuous production of welding fume in a closed chamber that the fume concentration in the air will not exceed about 600 mg./cubic meter of air regardless of rate or duration of production. At this air concentration the rate of production of fume is balanced by the rate of removal by agglomeration and gravitational settling. This simple example illustrates particle conditioning (agglomeration induced by vigorous Brownian Motion) and particle separation (gravitational settling). Agglomeration in itself produces no decrease in the dust concentration of the aerosol, but may make possible the effective use of a separating method which would otherwise be totally ineffective.

Two examples of induced agglomeration will serve to further illustrate particle conditioning:

1. Johnstone[5] and his co-workers have developed a particle conditioning device known as the Venturi scrubber. Air at very high velocities (20,000 fpm) is drawn through a Venturi throat into which is injected solid streams of water. The high velocity air disperses the liquid into a fine mist, and dust particles present in the air stream agglomerate with liquid droplets through impaction, condensation around the dust nuclei and by diffusion, effectively increasing the size and mass of the original particles. Following the Venturi scrubber, some device such as a wet centrifugal type separator (which would be rather ineffective on the original dust) can be used successfully to separate the resulting agglomerates from the air stream. Excellent results on many fine particles have been reported. For some materials, such as zinc oxide that are difficult to wet, the Venturi scrubber appears to be less effective. The use of this conditioning device is somewhat limited by its large energy requirements: a pressure drop of 15 to 20 inches of water gage. Most commercial air cleaners operate at two to four inches.

2. St. Clair,[6] Danser[7] and others report that aerosols may be rapidly agglomerated by intense high frequency sound waves. The more important factors causing sonic agglomeration are: (a) co-vibration of particles in a vibrating gas, (b) attractive and repulsive hydrodynamic forces between neighboring particles and (c) radiation pressure. Particle concentration is of great importance since if particles are too widely separated in the gas, an adequate degree of agglomeration may not be achieved. One grain per cubic foot is estimated to be the smallest effective concentration for sizes ranging from 1 to 10 microns. When the normal grain loading is too small, water, steam or some other liquid may be sprayed into the aerosol (or a second aerosol may be added to the first) to exceed the critical value. Although it is possible with great sonic intensity and long retention time to produce flocs of such size that gravitational settling becomes an effective separating mechanism, the equipment necessary to handle a reasonable quantity of gas by this method becomes excessive and the usual procedure is to produce flocs of 10 microns and larger that can be separated by efficient designs of cyclone dust collectors. While visual observation of the clearing of a dense aerosol by sonic agglomeration is most dramatic, there has been, to date, little use of this principal in industrial practice due to the difficulties of applying it to large air volumes and continuous operations.

These examples indicate some of the methods of particle conditioning and illustrate the relationship between particle conditioning and particle collection. The remainder of the discussion will cover particle separation and collecting devices.

Separation by Inertial Forces

A PARTICLE in a gravitational field of force will settle at a constant velocity given by Stokes' law (Equation No. 1):

$$V_{ts} = g/18 \frac{(\rho_s - \rho_a)d^2}{\mu}$$

where V_{ts} = terminal settling velocity (feet per second)

g = acceleration of gravity (feet per second per second)

ρ_s, ρ_a = density of solid and gas, respectively (pounds per cubic foot

d = particle diameter (feet)

μ = absolute viscosity of the gas (pounds per second per foot)

This equation is correct for spheres between 1 and 100 microns in diameter and has been shown to hold quite well for particles whose shape is somewhat different from spherical. Gravitational settling is an effective gas cleaning method for large particles only. For example, a 50 micron sphere of unit density settles in still air at the Stokes' law rate of 40 feet per minute. Since a settling chamber for continuous operation must of necessity contain a moving air stream, true settling velocity will probably be decreased by a factor of two. To handle a reasonable quantity of air, settling chambers must be made very large and are subject to convection currents which tend to re-suspend the fine dusts. To remove 50 micron mineral particles from 6,000 cubic feet of gas per minute, a settling chamber approximately seven feet high, 14 feet wide and 21 feet long is needed.

If the gravitational force in Stokes' equation is replaced by a centrifugal acceleration equal to V_t^2/R, where V_t is the tangential velocity (feet per second) and R is the radius of curvature (feet), the instantaneous radial velocity, V_R, imparted to the particle becomes (Equation No. 2):

$$V_R = \frac{V_t^2}{18R} \frac{(\rho_s - \rho_a)d^2}{\mu}$$

It has been demonstrated that sub-sieve size particles reach their terminal velocity almost as soon as they are acted on by a centrifugal field and no appreciable error is introduced by neglecting the initial brief acceleration of the particle. For practical application to small particles the tangential velocity of the particle may be taken as equal to the tangential air stream velocity. If aerosol particles are given a sufficiently high centrifugal acceleration by a sudden or continuous change in the direction of flow, they acquire a radial velocity component that produces movement across streamlines to a collecting surface where they can be removed. Dust collecting equipment employing this principle may take various forms such as impingers, impactors or centrifugal separators. These are often very efficient for large particles but are usually less effective for particles under 5 to 10 microns in diameter.

Equation 2 indicates that radial velocity is increased and separation efficiency improved by increase in tangential velocity and decrease in the radius of curvature of the air stream.

So-called impingement and impaction types of inertial dust collectors have been used to some extent for gas cleaning but by far the greatest number of collectors of this class, and indeed the most commonly used industrial dust collector of all, is the cyclone. Cyclones find wide application in forms ranging from multiple banks of one inch tubes to single units up to 15 and 20 feet in diameter.

In the simple tangential inlet cyclone collector the path of the conveying gas is unimpeded, traveling spirally downward from a tangential inlet and then upward to a central exit. The particulate matter is thrown out of the gas stream radially by centrifugal force, arrested in the slow-moving gas layer at the outer cyclone wall and directed downward into a collecting bin.

In attempts to improve their effectiveness, many modifications of the simple cyclone have been proposed. These include specially designed inlets, stationary or rotating internal parts and modified outlets, to mention but a few, yet in spite of intricate design these modified cyclones have not, in general, given results economically superior to well designed simple cyclones.

Cyclone performance is evaluated in terms of energy requirements, cleaning efficiency and cost of equipment maintenance.

Energy loss of rectangular inlet cyclones can be estimated from the following formula (Equation No. 3):

$$\triangle P = 0.0027 \frac{Q^2}{k\,e^2\,b\,h\left(\frac{L}{D}\right)^{1/3}\left(\frac{H}{D}\right)^{1/3}}$$

where $\triangle P$ = energy loss (inches of water gage)
Q = flow rate (cubic feet per second)
e = exit duct diameter (feet)
b, h = inlet width and height, respectively (feet)
L, H = height of cylinder and cone, respectively (feet)
D = cyclone cylinder diameter (feet)
k = a dimensionless factor descriptive of cyclone inlet vanes and having a value of 0.5 for cyclones without inlet vanes, 1.0 for inlet vanes that do not expand entering air stream or extend to exit duct wall, and 2.0 for inlet vanes which extend across entire annular space.

In terms of number of inlet velocity heads (F) the energy loss formula becomes (Equation No. 4):

$$F = 12\,\frac{\frac{b}{k}\,h}{e^2} \Big/ \left(\frac{L}{-}\right)^{1/3}\left(\frac{H}{D}\right)^{1/3}$$

This formula involves only the physical dimensions of the cyclone and indicates that all geometrically similar cyclones have the same energy loss for equal entry velocity. The physical basis for this equation is the observation that the flow pattern in all geometrically similar cyclones is identical.

Cyclones may be used to effectively reduce the load on a more efficient air cleaning device such as a filter, permitting smaller installations and more effective operation. Cyclones are most frequently used to remove the bulk of coarse dust and often this satisfies the air cleaning requirements for innocuous materials. Cyclones of this type may operate at pressure losses of one to two inches of water. High efficiency cyclones operate at energy losses up to five inches of water and are characterized by their small diameter, usually less than 12 inches. Adequate capacity is achieved by multiple banks of small units in parallel. Cyclones in series are seldom justified. Efficiencies close to 100 per cent can be expected with miniature cyclones on particle sizes down to five microns, whereas larger units seldom do well on particles less than 10 microns in size.

The purchase cost of simple, single unit cyclones is less than 10 cents per cubic foot per minute of air handled, but very small diameter multiple units, because of heavier construction and more intricate design, will generally cost about five times as much. Maintenance costs are generally low except when handling abrasive dusts or corrosive gases.

Gas Filtration

FILTRATION of aerosols may be accomplished by two methods.[9] In one, the filter material acts initially as a reasonably high efficiency filter but is primarily intended to provide a support for the rapid building up of a layer of aerosol particles which then acts as a very high efficiency filter. Resistance increases as the layer of particles increases and there is some penetration of the fibers of the filter. When the resistance reaches a pre-determined level, the filter cake is removed and the cycle repeated. After penetration of particles into the pores of the filter material the resistance, even after cleaning, is usually somewhat higher than it was initially. In the other type, the filter material itself acts as the removal medium and the composition and nature of the filter are important. This type of filter can seldom be cleaned successfully and when the resistance reaches a certain level the filter is discarded. Two forms may be distinguished, (1) very high efficiency, high resistance, low capacity filter papers such as the cellulose and asbestos filter media[11] and (2) poor to high efficiency, low resistance, high capacity deep-bed fibrous filters such as the fine glass fiber filters used as precleaners for high efficiency papers. In both, plugging of the filter with accumulated aerosol particles results in somewhat increased efficiency and in the case of the high efficiency papers, in greatly increased pressure drop.

Removal of particles from aerosols by filtration takes place by a variety of mechanisms depending upon the size and character of the particles. Since the pores of filters are many times larger than the material they remove, it is evident that

mechanical sieving is of little importance in gas cleaning except when a bed of the material being removed is built up on the surface. In this latter case sieving does assume some importance, and filtration through a bed composed of the material to be removed from the air has been found to be a very efficient method of gas cleaning.

Particles greater than two microns are removed principally by impingement, settling and inertial forces. Considering the manner in which flow takes place through a fibrous bed, it has been concluded that the streamlines bend around the fiber. Small particles tend to follow the streamlines of the gas and be carried around the surfaces of the fiber. Large, heavy particles traveling at high velocity will not follow the sudden bending but will tend to continue in a direct course and make contact with the fiber. The stream tube within which all particles greater than one to two microns will make contact with the fiber is the effective diameter. Effective diameter is always less than the true diameter. Direct interception plays a part for larger particles and the effective diameter must then be increased by an amount equal to the diameter of the particle. Gravitational settling becomes important if the particle has an appreciable Stokes' law settling rate. In this case its path will no longer coincide with any particular streamline in the air flow, and deposition of particles on fibers will occur as the aerosol penetrates the filter bed. The rate of deposition by gravitational settling is independent of flow through the filter bed, but inertial effects are improved by increased flow rate. Rodebush[10] has shown that the distance a particle will penetrate a gas before being brought to rest by the viscous forces is directly proportional to its initial velocity and the square of its diameter.

Particles between one and two microns tend to follow the streamlines around the fiber. At the poles of the fiber streamlines are crowded close to the surface and particles in this size range are sufficiently large to make streamlined contact with the fiber.

Particles below one micron in size are effectively filtered by diffusional and electrostatic forces. When particles are so small that they compare in size with the mean free path of the gas molecules, their Brownian Motion is violent and collisions with neighboring surfaces are frequent. The surfaces of the fibers in a filter add up to a large area so that the number of collisions is very great. Particles adhere to the fibers by intermolecular forces of the type known as Van der Waals forces which are effective over the surface of intimate contact between the particle and fiber. That this mechanism of particle collection is different from that of inertial forces and streamlined contact is evident from the observation that filtration of fine particles is adversely affected by increased velocity through the median. In addition, efficiency of deposition by diffusion is inversely proportional to particle diameter.

Electrostatic attraction between filter fibers and very fine particles plays an important role in high removal efficiencies exhibited by resin wool fibers. By carding powdered resin into the wool fibers a very high electrostatic charge is created. This charge persists for long periods but is adversely affected by wetting. Efficient filtration is not confined to particles carrying an electric charge of a certain sign since the resin particles are negatively charged and a compensating positive charge is induced on the ground fibers. Particles usually found in aerosols carry only small or zero charges so that breakdown of filters by negatively charged particles would be unlikely.

Fiber diameter is an important filter characteristic. For a given density of packing, finer fibers give a bed of greater surface area. This greatly improves the opportunities for capture of particles by diffusion and electrostatic attraction. In addition, decreasing the fiber diameter decreases the radius of curvature of streamlines around it, and results in more effective impaction and streamlined contact.

All of the above separating forces operate simultaneously during filtration of disperse dusts. Often, however, the characteristics of the particles as well as the desired degree of cleaning dictate the advisability of arranging matters to favor the action of one separating force over the others.

Flow through filters is generally stream-

lined and resistance is directly related to velocity and filter thickness by the following general equation (Equation No. 5):

$$\triangle P = KVX$$

where $\triangle P$ = pressure drop (inches of water)

V = velocity (feet per second)

x = bed thickness (feet)

and the coefficient K must be evaluated in terms of filter porosity; usually by empirical methods. Transitional and turbulent flow may take place in loosely packed fibrous filters operated at high flow rates. Equation 5 must then be modified accordingly.

In contrast to compacted or calendered fibers such as paper or felt, filters composed of a deep bed (one to four inches) of loosely packed fibers of spun glass, metal, rock wool or similar materials have low initial resistance in the neighborhood of 0.2 inches of water at rated capacity up to 400 feet per minute face velocity. These are generally cheap enough to be thrown away when dirty, although some commercial types can be cleaned. Deep bed filters can be made quite efficient by increasing the density of packing and decreasing the fiber diameter, but resistance increases with increase in efficiency. Low resistance fibrous filters are used principally in air conditioning and ventilating systems where they remove up to 50% of atmospheric dust by count. On a weight basis, efficiency is generally somewhat higher since only the larger particles will be removed; generally those greater than one to two microns. The life of the filter for this type of service is generally three to 12 months with normal atmospheric dust loadings of 0.2 to 0.5 grains per 1000 cubic feet of air. This type filter has considerable capacity for storing separated dust without excessive increase in pressure drop. Filters of this type cost about one cent per cubic foot per minute of rated capacity and are often used as prefilters or roughing filters to decrease the dust load on more efficient cleaners such as electrostatic precipitators.

Industrial air cleaning filters are generally made of woven or felted cotton and wool fibers constructed in the shape of tubes, bags, or screens. The initial efficiency of the cloth is generally greater than 90%, and efficiencies greater than 99% are usually obtained after the cloth has become plugged and a filter bed has been built up on the surface (generally but a few minutes under usual industrial loadings). Rated velocity through the cloth is between 10 and 50 feet per minute and initial cloth resistance is generally less than 0.5 inches of water. As the bed of filtered material accumulates, resistance increases and air volume decreases. Systems of this type are designed to operate to a pressure drop of two to four inches of water, after which the filter must be cleaned. This is accomplished by shaking, beating or otherwise dislodging the accumulated cake from the cloth and allowing it to fall into collecting bins. During the cleaning period the air flow must be cut off, necessitating standby units or an installation large enough to operate over the entire working period. Some tube filters are provided with traversing rings which move up and down the tube and automatically and continuously remove the accumulated filter bed by a reverse jet of air. By this means, cloth resistance can be maintained at a nearly constant value and cleaning efficiency also tends to remain constant in contrast to the units which are cleaned periodically. In the latter, efficiency increases as the bed accumulates and decreases after cleaning. The cost of filters of this type is 20 cents to one dollar per CFM, depending on size and mechanical features for automatic cleaning. Hot gases will weaken and destroy the fibers and moisture and oily, sticky particles will plug the filter.

The new cellulose and asbestos fiber filters come closer to being absolute filters than any other type of air cleaning device commercially available.[11] Less than 0.02% of dust in the size range 0.2 to 1.0 micron is passed by these filters when new, and efficiency improves rapidly with further use and remains at this high level until the dust load becomes so excessive that the units must be replaced. The initial resistance of the paper is about one inch of water gage for rated face velocities of five to six feet per minute, and the filter may be operated up to a resistance of six inches. Resistance increases rapidly with dust build up and the service life of the paper is ex-

tended by means of pre-filters which may have to be renewed several times before the final filter is rendered useless. This type of cleaner, including housing, pre-filters and final cleaner, costs approximately one and a half dollars per CFM of rated capacity and replacement costs are relatively high.

Moisture and acid gases will destroy the effectiveness of the paper and weaken the fibers sufficiently to cause holes and tears. Oily or greasy droplets and dusts will clog the pores of the paper and render it useless. Filtering velocity is very low and large numbers of filters are needed for handling reasonably large volumes of air.

Wet Scrubbers

MOST SO-CALLED gas scrubbers combine water sprays with conventional centrifugal and inertial type units and the improvement in dust removal can be attributed to other mechanisms than actual scrubbing of the dust-laden gas. For example, in the wet cyclone, liquid droplets (usually water) are sprayed radially through the rotating gas, and dust particles may become wetted by impingement on water droplets and by Brownian diffusion. In the case of hot moist gases the water may lower the temperature of the gases sufficiently to cause considerable condensation of liquid around dust particles which act as nuclei. In both these examples the liquid acts as a particle conditioner, making possible greater collection efficiency from the mechanical collector. True scrubbing may be accomplished by so thoroughly dispersing the gas in a liquid medium that the thickness of the gas elements approaches that of the particles to be separated. Under these conditions particles will migrate under the influence of diffusion and Stokes' settling to the water phase. Equipment capable of this type of cleaning is similar to the Theisen disintegrator and consumes about 10 HP per 1,000 CFM of gas. Conventional packed absorption towers and impingement type scrubbers are generally ineffective for small particles and suffer from plugging due to dust build up on the packing and plates. Air washers of the type used for air conditioning effect little decrease in the dust content of gases.

Wet methods have distinct advantages for the treatment of hot gases such as furnace effluents. Not only can the dust loading be reduced significantly but, by sufficient water treatment, the gases can be cooled to ambient temperatures. This greatly reduces the load on the fan and permits additional treatment, when necessary, by filtration devices which are not capable of withstanding high temperatures. In some cases disposal of the collected dust in the form of a slurry may be advantageous; while in others it may prove sufficiently disadvantageous as to rule out this method of gas cleaning.

The simpler types of scrubbers (gas washers, cyclones and impingement scrubbers) are not effective for particles below five microns. They operate at pressure drops ranging from two to eight inches of water and cost up to a dollar per CFM. Gas capacity is about the same as similar dry-types of collectors. The more efficient types of wet collectors are effective for particles down to one micron. They operate at pressure drops up to 20 inches of water and generally cost one dollar per CFM or more.

Electrostatic Precipitators

COLLECTION efficiencies on the order of 99.9% can be obtained with electrostatic precipitators on dusts below five microns. They can be used with wet gases, at temperatures up to 1200°F. and up to 10 atmospheres pressure. Two types are in general use; the single stage in which ionization and collection are combined, and the two stage in which ionization is achieved in the first section of the equipment and collection in a following section. Single stage units operate at high voltages and give highest efficiency. Two stage units are used for ventilation air cleaning and operate at 90% efficiency or less. Single stage precipitators operate at potentials up to 100,000 volts DC while two stage units seldom exceed 13,000 volts in the ionizing section and 6,000 in the collecting section.

Collection is effected by two forces: (1) ionization of particles and electrostatic attraction to charged collecting plates and (2) ionic bombardment of the electric wind created by the corona discharge. Precipitators are usually operated at the highest possible voltage without sparking to obtain high particle charge and precipitating

field. Efficiency of collection is favorably affected by long retention time and close spacing between alternately charged plates.

Electrostatic precipitators suffer from some serious disadvantages. The principal one being the possibility of resuspension of collected dust during spark discharges which may occur after excessive dust build up. Closely spaced collecting plates are difficult to clean and if combustible materials are being collected, fires can be started by spark discharges.

Gas velocities through the precipitator range from 200 to 600 feet per minute and the pressure drop is less than 0.5 inches of water. Single stage units range in cost from \$0.75 to \$2.50 per CFM while the two stage type seldom exceeds \$0.50 per CFM.

Gas Cleaning Problems

PRACTICAL GAS cleaning problems present so great a variety of situations that no set of specific rules can be laid down for their solution. For example, particle size and particle characteristics are seldom exactly duplicated even in the same general types of operation; the degree of gas cleaning economically desirable, or required by reason of health and safety, will vary with the nature of the material, the population density of the surrounding community, height of the discharge stack and the monetary value of the exhaust; methods available for recovery or disposal of the collected material may dictate the use of wet or dry collectors; high gas temperatures will rule out the use of cloth and paper filters; and combustible dusts and mists may make the use of electrostatic precipitators impossible. The above illustrates but a few of the factors that influence the selection of air cleaning devices. Nevertheless, in spite of the multiple variables, experience has indicated a few general principles and methods of procedure that should be heeded.

Certainly the first things to be learned are (1) the quantities and nature of the materials to be removed and (2) the degree of cleaning to be achieved. This information indicates the extent of the problem and sets the standards for the finished product. Most industrial gas cleaning problems resolve themselves into a choice of a single device which will produce the desired result at the cheapest cost. Some problems, however, are more complex and the purity standards for the effluent air exceptionally high. Satisfactory results can often be achieved only by the application of multiple air cleaners in series. For such applications there has been a tendency in some instances to rely on "safety in numbers" in preference to sound engineering. The results have been impressive in their failure.

If an aerosol contained particles of absolutely uniform size, and if natural agglomerative forces could be entirely eliminated, identical air cleaners in series would, in accordance with theory, remove a substantially constant percentage of the entering material. On this basis, if one unit were capable of removing 80% of the original material, three such units in series should remove better than 99% of the entering load. Experiments measuring the filtering efficiency of multiple layers of fibrous filter media against tobacco smoke (an aerosol consisting of uniform particles 0.3 micron in size) confirm this principle. Neither of these assumptions (uniform size and absence of agglomeration) is apt to be true in practice. Most aerosols contain a wide range of particle sizes and for this situation an air cleaner operating at 80% efficiency will remove the largest particles at close to 100% efficiency and the smallest particles at close to zero efficiency. As a consequence, material penetrating the first unit of the series contains few particles of a size that can be removed by succeeding units, and particles too small to be caught in the first unit will pass all subsequent similar units. In addition, agglomeration of particles, of great assistance in particle collection, is most likely to occur in, or prior to, the first unit where the particle concentration is greatest and the distance between particles the least. For these reasons, air cleaners with roughly the same characteristics and removal efficiency should not be used in series. It may be concluded from this that placing a less efficient air cleaning device downstream of a more efficient one is futile.

Due to the great toxicity of many of the materials handled in AEC installations and AEC contract plants, great reliance

has been placed on cellulose and asbestos paper filters.[11] The limitations of this medium (sensitivity to moisture and heat, low flow rate and high resistance) have already been pointed out. In spite of these disadvantages, materials of this type have been doing a good job under proper conditions of use. To lengthen the service life of the paper, it should be preceded by some type of roughing filter. This usually takes the form of a deep bed filter composed of fine, densely packed glass fibers which remove up to 90% of the entering dust load. If the aerosol dust loading is heavy, the fiber filter should in turn be preceded by some device which will remove the major bulk of the material. This may be accomplished by a dry cyclone; preferably a high efficiency type, to decrease as much as possible the load on the fiber pre-filter.

In the treatment of hot furnace effluents, it will be necessary to cool the gases before passing them through the paper filter. This may be done conveniently by a wet scrubber or wet cyclone. Efficient collectors of this type will cool the gases to close to ambient temperature and will remove almost all material greater than ten microns, plus an appreciable number of particles between two and 10 microns. Prior to final filtration, the moist gases must be heated to eliminate water droplets and prevent condensation in the filter. In those cases where incombustible filters are objectionable, cotton fibers can be substituted for the fiber glass pre-filters. In this hypothetical system for the cleaning of hot furnace gases it will be noted that in step one, the gases are cooled and the bulk of the dust load is removed in a wet collector. In step two the gases are reheated to eliminate moisture in preparation for filtration. In step three all but the very finest particles are removed by the fibrous, deep bed pre-filter, and, finally, in step four the remaining dust is removed by a very high efficiency cellulose and asbestos filter. This illustrates how air cleaners of different characteristics and efficiency may be effectively combined. When additional treatment is required for removal of gaseous constituents of the furnace effluent, this can most conveniently be accomplished after removal of the solids since fouling and plugging of gas absorption towers and columns has been a common experience when working with dirty gases.

This discussion of air cleaning methods and devices may be summed up with the observation that the tools now available for the cleaning of stack effluents are adequate for the job when applied with sound engineering. Research, of which there is a great deal going on at the present time, will undoubtedly point the way to more effective and more efficient methods in the future.

Bibliography

1. DRINKER, P. and HATCH, T.: Industrial Dust. McGraw-Hill Book Co., New York, 1936.

2. WHYTLAW-GRAY, R. and PATTERSON, H. S.: Smoke: A Study of Aerial Disperse Systems. Edward Arnold Co., London, 1932.

3. GIBBS, WILLIAM E.: Clouds and Smokes. P. Blakiston's Sons and Co., Philadelphia, 1924.

4. SILVERMAN, LESLIE, Private Communication.

5. JOHNSTONE, H. F. and ROBERTS, M. H.: Deposition of Aerosol Particles from Moving Gas Streams. *Ind. & Eng. Chem.*, 41:2417, 1949.

6. ST. CLAIR, H. W.: Agglomeration of Smoke, Fog or Dust Particles by Sonic Waves. *Ibid*, 2434.

7. DANSER, H. W. and NEUMANN, E. P.: Industrial Sonic Agglomeration and Collection Systems. *Ibid*, 2439.

8. FIRST, M. W.: Fundamental Factors in the Design of Cyclone Dust Collectors. Sc.D. Thesis, Harvard University, 1950.

9. SILVERMAN, L.: Filtration Through Porous Materials. *Am. Ind. Hyg. Ass'n. Quart.*, 11:1, March, 1950.

10. RODEBUSH, W. H.: Filtration of Aerosols. *Handbook on Aerosols*, U.S.A.E.C., Washington, D.C., 1950.

11. SMITH, W. J. and STAFFORD, E.: New Dust Filters Giving Unequalled Results, *Chem. Eng.*, 105, Aug. 1950.

Effectiveness of Gauze Respirator for Sulphuric Acid Mist

ABRAHAM WALLACH,
Director of Division of Industrial Hygiene,
Montana State Board of Health

IN MAKING a study of the exposure of workers to sulphuric acid mist (containing zinc sulphate) in a zinc electro refinery, it was found that the general practice was to use a "home-made" respirator consisting of eight to 12 layers of ordinary gauze, 28 to 30 mesh (number of square openings per linear inch), on a copper wire framework.

Since this device had the advantages of minimizing (if not eliminating) the dermatitis problem caused at times by the standard respirator for acid mist, of having practically no noticeable resistance to breathing, and being much less expensive, various experiments were run to determine the filtering efficiency of the layers of gauze.

Apparatus and Procedure

ACCORDING to Henderson and Haggard[1] an average adult male (while standing) breathes eight liters per minute (lpm.), while walking at two miles per hour 14 lpm., and during a slow run 43 lpm. The effective breathing cross section of the gauze device was 6.25 square inches. This meant that the air flow through the gauze during inspiration for various degrees of physical activity ranged from 2.5 to 4.5 to 13.8 lpm. per square inch of gauze surface, since inspiration takes approximately half the time of breathing.

To determine the efficiency of the gauze, two standard impingers were placed side by side under varying mist concentrations. (It was practically impossible to sample through the gauze itself while being worn by the worker. Also, the sampling rates necessary for significant samples would have materially affected the air flow through the gauze.) One impinger was used to determine the atmospheric contamination. To the other, a short-stemmed funnel—the bowl of which was covered with layers of gauze held in place with an elastic band—was connected in series by a short piece of rubber tubing, the glass stem being in direct contact with the entrance of the impinger. To simulate the range of breathing conditions mentioned above, the air was passed at varying rates (0.8 to 1.1 cfm.) through funnels having different diameters on top. Aluminum guards, similar to those used with the midget impinger, were placed over the funnel mouth and the entrance of the impinger (used for air concentrations) to prevent possible contamination of the samples.

Seventy to 90 ml. of water were used in the impingers. (Preliminary tests using two impingers in series showed a collecting efficiency of from 98.5 to 100 percent at the sampling rates used.) After sampling, the volume of liquid was made up to 100 ml., 80 ml. of which were used for determining the sulphuric acid and the remainder for zinc sulphate. The acid was determined by titrating with N/50 NaOH, first boiling out the carbon dioxide to insure a sharp end point. The zinc sulphate was determined by running zinc polarographically,[2] and calculating the equivalent weight of the zinc salt. The funnel was washed with distilled water after each run, the washings falling into the impinger with which it was connected in series. (A number of tests showed that for 50 minute-sampling periods from 1 to 8% of the mist coming through the gauze clung to the bowl of the funnel.)

The error of the acid determination ranged from 0.03 to 0.13 mg. per cm. of air depending upon the sampling period (20 to five minutes) and rate. In terms of affecting the accuracy of the gauze efficiency data, the maximum percentage error varied from 1.3 to 6.5% depending upon the sulphuric acid content of the air (10 to 2 mg. per cm.). The accuracy of the equivalent data relating to zinc sulphate was in the same range. The sampling accuracy (air flow) was + or − 3%.

The tests were run in temperatures varying from 54° to 68°F, relative humidity varying from 48 to 65%, and atmospheric pressure varying from 24.5 to 25 inches of mercury.

To eliminate the possibility that the

gauze was treated with a significant amount of chemicals to neutralize the acid mist coming through, eight layers of 6 in. x 7 in. (about 6.5 times the effective breathing area of the respirator device) was soaked in water for thirty minutes and titrated. Less than 0.05 milliliters of fiftieth normal sulphuric acid was needed.

Experimental Results and Discussion

ALL TESTS were made in atmospheres containing sulphuric acid in concentrations greater than 1.0 mg. per cm. of air, the latest threshold limit adopted by the American Conference of Governmental Industrial Hygienists. Table I shows the data obtained by using eight layers of *fresh* gauze at the start of each run under varying conditions.

The data are grouped arbitrarily in three sections according to acid mist concentrations in the air: 0 to 3.9, 4.0 to 7.9, and 8.0+ mg. acid per cm. of air. Within each section the results are listed in order of rate of air flow through the gauze layers.

An examination of Table I indicates the following:

(a) In the main, there is a filtering efficiency of 90% or better in atmospheres of from 1.5 to 11 mg. acid mist per cm. of air. In all cases but one, the mist coming through the gauze contained less than the maximum allowable concentration for an eight-hour work day.

(b) Generally, the filtering efficiency on each run for acid and zinc sulphate respectively, check fairly well within limits of experimental error. However, there is a sharp discrepancy in runs No. 1 and No. 2.

(c) There is no conclusive evidence of a correlation between filtering efficiency of the layers of gauze and mist concentration.

(d) There is some evidence showing a higher collecting efficiency with an increase in air flow through the gauze.

In order to follow the code set up by the National Bureau of Standards[3] for testing mechanical-filter respirators, starting with eight layers of fresh gauze, air containing 10 to 14 mg. acid per cm. was passed through the same pad of gauze for five successive periods, each lasting 50 minutes. The tests would be an indication not only of the effectiveness of the gauze after four hours of usage, but also of the change of the filtering efficiency with time of use. Similar runs, but of much shorter duration, were made on gauze of 10 and 6 layers respectively. The results obtained from this series of experiments are given in Table II.

The above data indicate the following:

(a) With eight layers, the filtering efficiency varies between 83.5 to almost 90% at acid concentrations of from 10 to 14 mg. per cm. of air. With ten layers, the efficiency is somewhat higher, 88 to 95%

TABLE I.
FILTERING EFFICIENCY OF EIGHT LAYERS FRESH GAUZE

Run No.	Sampling time (min.)	Air-flow through gauze (lpm/sq. in.)	Sulphuric Acid Air*	Sulphuric Acid Gauze*	Sulphuric Acid % through	Zinc Sulphate Air*	Zinc Sulphate Gauze*	Zinc Sulphate % through
1	15	3.6	2.58	0.18	7.0	7.65	1.58	20.6
2	15	5.4	1.43	< 0.05	< 3.5	7.50	0.93	12.4
3	10	5.8	3.58	0.11	3.1	7.04	0.42	6.0
4	10	5.8	3.50	0.07	2.0	6.51	0.60	9.2
5	10	5.8	2.73	0.11	4.0	7.52	0.42	5.6
6	15	10.8	2.36	< 0.05	< 2.1	6.22	0.31	5.0
7	15	3.6	5.76	1.09	18.9	8.45	1.21	14.3
8	15	3.6	5.15	0.75	14.6	8.25	1.32	16.0
9	10	5.8	4.11	0.07	1.7	7.04	0.60	8.5
10	20	5.8	5.66	0.35	6.2	11.55	0.69	5.9
11	20	5.8	4.97	0.25	5.0	10.28	0.57	5.5
12	20	5.8	4.35	0.25	5.8	10.28	0.57	5.5
13	15	10.8	4.85	0.41	8.5	8.07	0.31	3.8
14	15	12.1	6.94	0.62	8.9	9.37	0.23	2.5
15	10	5.8	9.55	0.46	4.8	17.30	1.27	7.3
16	10	5.8	8.18	0.49	6.0	14.40	1.45	10.0
17	20	5.8	11.20	0.46	4.1	18.80	1.25	6.6
18	20	5.8	9.45	0.54	5.7	18.10	1.06	5.9
19	20	5.8	8.88	0.48	5.4	15.80	1.06	6.7

*mg/cm. of contaminant in atmosphere or gone through gauze.

TABLE II.
FILTERING EFFICIENCY OF SAME LAYERS OF GAUZE SUCCESSIVELY

Run	No. of layers	Sampling time	Air-flow through gauze	Sulphuric Acid			Zinc Sulphate		
No.	used	(min.)	(lpm./sq. in.)	Air*	Gauze*	% through	Air*	Gauze*	% through
20	Same	50	5.8	11.3	1.18	10.5	16.8	1.51	9.0
21	8 layers	50	5.8	11.5	1.52	13.2	17.6	2.06	11.7
22	through-	50	5.8	10.1	1.25	12.4	15.5	1.65	10.6
23**	out	50	5.8	10.5	1.73	16.5	15.9	2.23	14.0
24		50	5.8	14.3	1.51	10.6	21.2	2.06	9.7
25	Same	10	5.8	6.26	0.53	8.5	11.50	0.95	8.3
26	10 layers	10	5.8	4.40	0.53	12.0	8.05	0.78	9.7
27	through-	10	5.8	5.24	0.53	10.1	8.94	0.71	8.0
28	out	10	5.8	5.24	0.46	8.8	9.52	0.60	6.3
29		10	5.8	3.95	0.43	10.9	7.52	0.60	8.0
30		10	5.8	5.24	0.22	4.2	8.94	0.60	6.7
31	Same	15	4.8	6.89	1.31	19.0	***		
32	6 layers	15	4.8	8.00	0.62	7.8			
33	through-	15	4.8	7.72	0.82	10.6			
34	out	15	4.8	6.10	1.19	19.5			
35		15	4.8	6.64	1.53	23.1			

*mg./cm. of contaminant in atmosphere or gone through gauze.
**crystals were visible on top of gauze after 2½ hrs. sampling.
***not analyzed.

TABLE III.
FILTERING EFFICIENCY OF EIGHT LAYERS DAMP USED GAUZE

Run	Time gauze used	Sampling time	Air-flow through gauze	Sulphur Acid			Zinc Sulphate		
No.	(hrs.)	(min.)	(lpm/sq. in.)	Air*	Gauze*	% through	Air*	Gauze*	% through
36	1.5	5	3.6	2.73	0.00	0.0	8.74	1.92	22.0
37	1.0	10	11.2	2.00	$<$0.04	$<$2.0	8.63	0.63	7.3
38	1.5	5	3.6	5.91	0.00	0.0	9.19	0.45	4.9
39	2.0	5	5.8	5.24	0.00	0.0	10.85	1.22	11.2
40	2.3	5	5.8	5.24	0.00	0.0	10.32	1.06	10.2
41	1.7	5	11.9	5.73	0.00	0.0	8.75	0.00	0.0
42	1.0	5	5.8	9.70	0.85	8.8	20.20	2.96	14.6
43	1.5	5	5.8	11.20	0.78	7.2	20.90	2.54	12.2
44	2.5	5	5.8	9.32	0.02	0.2	16.26	1.53	9.4

*mg./cm. of contaminant in atmosphere or gone through gauze.

(albeit in atmospheres of half the mist concentration). With six layers, the effectiveness is definitely lowered.

(b) Where the filtering efficiencies were run for acid and salt respectively, (eight and 10 layers) they checked quite well within experimental error.

(c) In all three groups of tests, there is no clear correlation between effectiveness of the gauze pad and its length of usage (time). Nevertheless, a comparison with Table I shows that fresh unused gauze—under similar conditions of mist concentration and breathing rates—is more effective for the first 10 to 20 minutes. (Compare runs 15-19 with 20-24, runs 9-12 with 25-30, despite 10 layers being used in the latter group.)

The respirator device described has no exhalation valve, so that the worker exhales, as well as inhales, through the gauze. Thus, after a short period of use, the gauze becomes damp from the moisture in the exhaled breath. In order to determine possible effects of this moisture, tests were made on pads of gauze (obtained from workers and the writer) which had been in use from 1 to 2½ hours. The sampling runs were usually not longer than eight minutes, for it was found that a steady air flow through the damp gauze for longer periods would dry it. A summary of the findings (grouped by acid mist concentrations in the air) is shown above in Table III.

A comparison with Table I shows that the damp gauze, although used for periods of from 1 to 2½ hours, is just as effective as fresh gauze for filtering out the zinc sulphate and even more effective with the acid. (Compare run 36 with 1, 37 with 6, 38 with 7, and 8, 39 and 40 with 9-12, etc.) Apparently, the moisture from the breath on the gauze helps act as a trap for the

mist. Thus, to test the filtering efficiency of such a device, instead of using the procedure designated by the National Bureau of Standards, one should have the device worn under operating plant conditions for four to five hours, and then test it for a five to eight minute run (longer runs would completely evaporate the dampness on the gauze).

The significant discrepancies of filtering efficiency percentages for the acid and salt, in most of the runs, are not understandable. However, as in Table I, generally there appears to be better results with higher air flow.

Since the above results showed that eight layers of either fresh or used (under actual working conditions) gauze were effective, in atmospheres having up to 11 mg. sulphuric acid per cm. of air, in keeping inspired air under the maximum permissible limit of 1.0 mg. per cm.; it was decided to run similar tests with only 6 layers of gauze. Results are shown in Tables IV and V.

Similarly to the results obtained with eight layers, those with six layers show that used damp gauze is as effective as fresh gauze. Also, six layers are effective in keeping the acid mist in inspired air below the mpl. where atmospheric sulphuric acid contamination is as high as 9 mg. per cm.

Discrepancies in filtering efficiency on a number of runs in Tables IV and V are quite apparent. Why the effectiveness in removing acid is much greater for the six minute runs with both fresh and used gauze as compared to removing zinc sulphate is not understood. It is also not understood why in Table IV the "percentages through" for acid is much greater in the 15-minute runs as compared to the six-minute runs, yet the reverse is true with the zinc sulphate results. Nevertheless, the data in both tables indicate that filtering efficiency increases somewhat with increased inspiration rates.

This phenomenon (higher efficiencies at greater rates of air flow), which is also indicated by Tables I and III, may possibly be related to the fact that the standard impinger collecting efficiency for dusts and fumes increases with an increase in velocity.[4,5] Although the over-all air velocity for one layer of gauze would be much less than that usually obtained with the impinger, if there is an optimum overlapping of the fibers of one layer to the next—especially with eight to 10 thicknesses—the velocity through the actual air spaces of the gauze pad may easily be in the same range. And under such conditions there would be deposition of the mist by impaction[6] on the fibers of each successive layer of gauze.

As would be expected, a comparison of results obtained under similar conditions with eight and six layers, shows the thicker pad usually more effective. (Compare run

TABLE IV.
FILTERING EFFICIENCY OF SIX LAYERS FRESH GAUZE

Run No.	Sampling time (min.)	Air-flow through gauze (lpm/sq. in.)	Sulphuric Acid: Air*	Sulphuric Acid: Gauze*	Sulphuric Acid: % through	Zinc Sulphate: Air*	Zinc Sulphate: Gauze*	Zinc Sulphate: % through
45	15	3.6	6.00	0.94	15.7	10.55	1.85	17.5
46	15	5.3	5.48	0.85	15.6	10.67	1.14	10.7
47	15	10.8	5.33	0.52	9.8	11.67	0.96	8.3
48	6	3.6	5.46	0.19	3.8	7.88	2.54	32.3
49	6	5.1	5.00	0.07	1.4	8.04	1.67	20.8
50	6	9.8	5.54	0.00	0.0	10.00	1.21	12.1

TABLE V.
FILTERING EFFICIENCY OF SIX LAYERS DAMP USED GAUZE

Run No.	Time gauze used (hrs.)	Sampling time (min.)	Air-flow through gauze (lpm/sq. in.)	Sulphuric Acid: Air*	Sulphuric Acid: Gauze*	Sulphuric Acid: % through	Zinc Sulphate: Air*	Zinc Sulphate: Gauze*	Zinc Sulphate: % through
51	1.3	8	3.6	9.26	0.70	7.6	15.88	2.61	16.5
52	1.0	8	10.3	7.10	0.71	10.0	12.63	0.76	6.0
53	0.7	6	3.6	3.95	0.00	0.0	6.13	1.42	23.1
54	0.5	6	10.6	5.23	0.00	0.0	8.25	1.12	13.6

*mg./cm. of contaminant in atmosphere or gone through gauze.

46 with 9-12, 47 with 13 and 14, 52 and 54 with 41, 53 with 58.)

To determine the resistance to breathing of the gauze device, 10 layers of gauze were placed over a funnel having a cross section on top of 2.4 square inches and held securely with a rubber band. Air was passed through at a rate of 42 lpm. or 17.5 lpm. per square inch of gauze—equivalent to the lower range of maximum physical exertion for an adult male. The pressure drop across the gauze layers was less than 1/16 inch of water, which compares quite favorably with two inches and one inch permitted[3] for inhalation and exhalation, respectively.

Summary

COMMERCIAL untreated gauze, 30 mesh, on a suitable wire frame appears to be an effective respirator for sulphuric acid mist. With eight to 10 layers of gauze, the inspired air will contain less than the maximum permissible limit of 1.0 mg. per cm. in atmospheres containing as high a concentration of 11 mg. per cm. With six layers, such results were obtained in atmospheres containing as much as 9 mg. per cm. Eight to 10 layers are somewhat more effective than 6. Such a device may possibly be used effectively for particulate air contaminants having the same particle size, and which act primarily in proportion to mass (rather than number of particles). Chromic acid mist from electroplating would be an example, since in the study made, the mist was caused by small gas bubbles escaping through a liquid surface. Resistance of the pad to inhalation and exhalation is less than 1/16 inch of water under breathing conditions equivalent to maximum physical exertion.

Under the conditions run, there was no conclusive evidence of correlation between filtering efficiency of the gauze and mist concentration in the atmosphere. There is some evidence of a higher efficiency with faster breathing rates. (This is beneficial, since with faster breathing the relative amounts of total mist inhaled would decrease.) The dampness on the gauze from the exhaled breath also increases the filtering efficiency.

Such a device is of practical value, especially for workers exposed continuously to excessive amounts of sulphuric acid mist over a three to four hour period and where no feasible engineering control seems possible. It has the advantages over the usual acid mist filter-type respirator approved by the United States Bureau of Mines in that it minimizes the dermatitis problem to the face, has practically no resistance in breathing, and the "cartridge" replacements are less expensive.

ACKNOWLEDGMENT: The author wishes to express his appreciation to MR. O. L. OLSGAARD for assistance in sampling and MR. L. S. CHAMPA for running the zinc determinations.

Bibliography

1. HENDERSON, YANDELL and HAGGARD, H. W.: "Noxious Gases," Second Revised Edition, p. 18, Reinhold Publishing Co., New York, 1943.

2. CHAMPA, LUDWIG, S., and WALLACH, ABRAHAM: Analytical Chemistry, 22:727 (May,) 1950.

3. National Bureau of Standards, U.S. Dept. of Commerce: "American Standard Safety Code for the Protection of Heads, Eyes and Respiratory Organs." pp. 34-36. Handbook H24, 1938.

4. KEENAN, ROBERT G., and FAIRHALL, LAWRENCE T.: "The Absolute Efficiency of the Impinger and the Electrostatic Precipitator in the Sampling of Air Containing Metallic Lead Fume." *Indust. J. Hyg. & Tox.*, 26:241 (September) 1944.

5. HATCH, THEODORE, et al.: "Modified Form of the Greenburg-Smith Impinger for Field Use, with a Study of its Operating Characteristics." *Indust. Hyg.*, 14:301 (October) 1932.

6. JOHNSTONE, H. F., and ROBERTS, M. H.: "Deposition of Aerosol Particles from Moving Gas Streams." *Ind. Eng. Chemistry*, 41:2417 (November) 1949.

Scientific Exhibits in Atlantic City

THE SCIENTIFIC Exhibits Committee is making plans for an interesting group of exhibits at the 1951 Industrial Health Conference at Atlantic City, April 21 to 28, 1950. Prizes will be awarded for the most outstanding exhibits. Applications for space in this section should be made to ALLAN E. DOOLEY, Health Division, The Texas Company, 135 East 42nd Street, New York 17, New York. Inasmuch as available space will be limited, applications should be made promptly so that the committee can carefully consider them.

National Noise Abatement Symposium

October, 1950
Chicago

THE INCREASED interest in noise, its effect on hearing, and methods of measurement and control was evidenced by a comprehensive program sponsored jointly by the Armour Research Foundation of Illinois Institute of Technology and the National Noise Abatement Council at Chicago on October 20, 1950. HUGH KNOWLES, presiding chairman, President of Industrial Research Products Company, Franklin Park Illinois, set up the broad but useful definition of noise as "an unwanted sound."

"The Effect of Noise on Hearing, Morale, and Efficiency" was discussed by DR. HALLOWELL DAVIS, Director of Research, Central Institute for the Deaf, St. Louis, Missouri. DR. DAVIS made reference to a critical survey recently reported by DR. KREITER, now with the U.S. Navy at Bolling Field, Washington, D.C., and published in full as Special Reprint No. 1 of the *Journal of Speech & Hearing*. He pointed out that the limits within which noise affects hearing are still vague and uncertain. Some of the present ideas concerning the effects of noise, it must be admitted, are made on the basis of data which are not founded on research work conducted with scientific rigor. It can be stated definitely that injury to hearing due to noise is now generally accepted, as is the added concept that noise can be annoying. It has been found that 50% of one group of subjects was made more irritable on being subjected to noise. The higher frequencies produced more irritation than the lower. It can be considered only as a good guess that the critical band of noise intensity is at 85 decibels. However, he felt that the maximum safe level over all frequencies on the basis of information so far developed should be taken as 85 decibels or 0.0002 dynes per square centimeter. In regard to ear plugs, DR. DAVIS stated that a reduction of 20 to 30 decibels can be obtained and that speech communications in a noisy environment can be improved by workers wearing ear plugs. It has been the experience that some people cannot wear these with comfort. From a practical point of view the most important effect of noise is interference with communication from one person to another—and this occurs at levels below those producing injury. From a production point of view, the effect of excessive noise is greatest where output depends upon communication by speech. It is interesting to note that noise can be actually desirable in some instances. For example, disturbing voices down the hall from a hospital room were very annoying to a patient but upon the addition of a hum from turning on a fan the disturbing voices were masked and annoyance to the patient ceased. However, effects of this type are difficult to measure by meters. Concerning ultrasonic noise, DR. DAVIS noted that though frequencies of such noise are by definition above the audible, there are usually accompanying lower and audible frequencies. In regard to ultrasonic levels, the data are still too conflicting to permit generalizations.

DOUGLAS E. WHEELER, Field Representative of the Sub-Committee on Noise in Industry, Committee on Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology, Los Angeles, discussed "Noise Abatement in Connection with Hearing." MR. WHEELER observed that we must acknowledge that noise does damage hearing. As early as 1890, DR. W. E. GROVE, Chairman of this Committee, demonstrated hearing loss among boiler makers. The vulnerability of the ear to high intensity noise is accentuated by the fact that the ear is always wide open and cannot govern the ambient energy that reaches it as can the eye which has the protection of the iris and the eyelid. The important facts in noise are the intensity, the frequency, and the duration of exposure. The first losses are usually in the higher frequencies. The question of "how much noise is too much" and "what duration is too long" has not yet been answered. Analysis of individual audiograms of groups of young men who are being placed in noisy shipyard work over a four-year period should go far in giving us additional quantitative data on these important factors. The first observations after six months of such work were presented, and it was noted that the composite losses of the selected group over the entire spectrum was less than 10 decibels. Of 175 men exposed to greater intensities than 125 decibels, 45% retained normal hearing and 25% had a severe bilateral hearing loss. MR. WHEELER stated that the Academy Committee on Conservation of Hearing recommends that pre-employment audiograms should become part of the medical examination and that hearing acuity of workers should be rechecked at the minimum interval feasible wherever occupations involve exposures to noise at levels

greater than 90 decibels. In the abatement of noise in connection with hearing, the noise should be controlled at its source wherever possible. In respect to ear plugs, the essential requirements are that they must be comfortable, must give effective attentuation of the noise, and the first cost and replacement cost must be low. However, the matter of comfort is a highly personal factor as is evidenced by the experience with one man who replaced a carefully designed ear plug with a No. 8 round-head machine screw! Allergic reaction from rubber or mechanical irritation in the ear canal must be considered in offering ear protectors for use. Ear protectors will usually reduce the amount of sound transmitted to the ear by 25 to 35 decibels. It is difficult to obtain more than 60 decibel decrease even by the best ear protector available. MR. WHEELER presented a number of composite audiograms showing loss of hearing of workers exposed to 105 decibels between the start of a day's work and the end of the shift, including a comparison of the loss experienced by workers in this environment with and without the protection of ear plugs.

LEO L. BERANEK, Associate Professor of Communications Engineering, and Technical Director of the Acoustics Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts, presented a technical discussion of "Apparatus for Noise Measurement." Noise measuring equipment consists of at least a microphone, an amplifier, a calibrated attenuator and an indicating meter. A single meter reading is often not adequate to describe a noise, so that analyzing equipment is needed to determine the amplitudes and frequencies of the component sounds. The basic instrument, around which other noise measuring equipment must be assembled, is the sound-level meter. The characteristics of satisfactory sound-level meters and such component parts as the amplifier are reviewed.

Six types of microphones for use with sound-meters were described, together with their various advantages. The principal differences between them are frequency range covered, sensitivity, cost and temperature, pressure and humidity performance. The units included were the Rochelle salt crystal type, the moving-coil type, the barium titanate ceramic type, the condensor type, the ribbon type, and the ammonium dihydrogen phosphate (ADP) crystal type. In the study of a machine which is creating noise, the amplitude of vibration of the radiating surfaces is often desired. These amplitudes may be determined in the frequency range above 20 cycles per second by the use of a suitable vibration pickup and the basic sound level meter. Three types of vibration pick-ups are commonly employed: the Rochelle salt, the barium titanate and the moving-coil dynamic.

Analyzers are required whenever a knowledge of the distribution of sound pressure as a function of frequency is desired. Such a frequency distribution may be needed to determine the magnitude and frequency of particular components of a noise which it is desired to reduce. Such quantities as loudness, speech interference level, aircraft comfort level and articulation index require frequency analysis for their determination. Any of six types of analyzers may be selected for these purposes, depending upon the problem.

A sound-level calibrator is necessary for checking the accuracy of sound measuring equipment. The principal manufacturers of these instruments have each devised a method of checking the calibration. BERANEK checks the calibration of a noise measuring system at the start and finish of a job and each half-day in between if the test is long.

JAMES H. STERNER, M.D., Associate Medical Director of the Eastman Kodak Company, Chairman of the Committee on Physical Agents of a Hazardous Nature of the American Medical Association Council of Industrial Health, and a past-president of the American Industrial Hygiene Association, presented the luncheon address on the subject "Are We Ready for Standards of Noise?" The general purport of Sterner's presentation, the entire text of which will appear in an early issue of Industrial Medicine and Surgery was that so far basic information is as yet inadequate for setting up definite standards on noise. However, he did point out that it was the consensus of opinion of the Joint Committee on Noise of the A.M.A. and the A.A.O. & O. at the February 1950 meeting that the standards will have to be expressed in terms of intensity levels in various frequency levels rather than as a single level for the over-all spectrum.

Papers of much practical value on various aspects of noise control were presented by HOWARD C. HARDY, Supervisor of Acoustics and Vibrations Research, Armour Research Foundation; C. M. ASHLEY, Chief Development Engineer, Carrier Corporation, Syracuse, New York; CYRIL M. HARRIS, Member of the Technical Staff, Bell Telephone Laboratories, Murray Hill, New Jersey; and C. D. YAFFE, Chief, Field Section, Federal Security Agency, Public Health Service, Cincinnati, Ohio. These together with the foregoing papers are soon to be published by the National Noise Abatement Council and Armour Research Foundation of Illinois Institute of Technology.

Stocks of PHS Publications Available for Free Distribution

Stocks of the publications listed below have been received by the Division of Industrial Hygiene, PHS, and are available upon request as long as the supply lasts. To request copies of any of these publications, address the Information Section, Division of Industrial Hygiene, Public Health Service, FSA, Washington 25, D.C. The abbreviations used below are PHR, *Public Health Reports;* NIHB, *National Institutes of Health Bulletin;* PHB, *Public Health Bulletin.*

Twenty-four-hour Output of Certain Urinary Constituents in Persons Exposed to Lead Arsenate Spray Residue. PHR Reprint No. 2318.

Public Health Administrator's Responsibility in Field of Occupational Disease Legislation. PHR Reprint No. 2325.

Coding and Tabulation of Medical and Research Data for Statistical Analysis. PHR Reprint No. 2346.

Clothing for Protection Against Occupational Skin Irritants. PHR Reprint No. 2383.

Practical Plan for Treatment of Superficial Fungous Infections. PHR Reprint No. 2453.

Dental Status of Adult Male Mine and Smelter Workers. PHR Reprint No. 2355.

Outbreak of Dermatitis From Airplane Engine Covers. PHR Reprint No. 2472.

Effect of Arsenates on Storage of Lead. PHR Reprint No. 2485.

Studies on Strains of *Aerobacter cloacae* Responsible for Acute Illness Among Workers Using Low-Grade Stained Cotton. PHR Reprint No. 2496.

Sickness Absenteeism Among Male and Female Industrial Workers During 1943 and Among Males During the First and Second Quarters of 1944, With a Note on the Respiratory Epidemic of 1943-44. PHR Reprint No. 2578.

Age Factor in Disabling Morbidity, 1940-44. PHR Reprint No. 2680.

Industrial Control Chart Applied to the Study of Epidemics. PHR Reprint No. 2748.

Sickness Absenteeism Among Male and Female Industrial Workers During 1945, With a Note on the Respiratory Epidemic of 1945-46. PHR Reprint No. 2755.

Formaldehyde—Its Toxicity and Potential Dangers. PHR Supplement 181.

An Evaluation of Neurologic Symptoms and Findings Occurring Among TNT Workers. PHR Supplement 196.

Thallium—a Review and Summary of Medical Literature. PHR Supplement 197.

Studies in Chronic Selenosis. NIHB No. 174.

Industrial Manganese Poisoning. NIHB No. 182.

Effects of Aliphatic Nitrous and Nitric Acid Esters on Physiological Functions With Special Reference to Their Chemical Constitution. NIHB No. 186.

Xylidine (C,C-dimethylaniline): Its Toxicity and Potential Dangers as Compared With Those of Aniline and an Appraisal of Potential Hazards From Its Use in Blending Gasoline. NIHB No. 188.

Phenol and Its Derivatives: Its Relation Between Their Chemical Constitution and Their Effect on Organism. NIHB No. 190.

Relation Between Toxic Action of Chlorinated Methanes and Their Chemical and Physiochemical Properties. NIHB No. 191.

Relative Toxicity of Lead and Some of Its Common Compounds. PHB No. 253.

Preliminary Survey of Industrial Hygiene Problem in United States. PHB No. 259.

Fatigue and Hours of Service of Interstate Truck Drivers. PHB No. 265.

Aromatic Amino and Nitro Compounds, Their Toxicity and Potential Dangers. PHB No. 271.

Toxicity and Potential Dangers of Nitrous Fumes. PHB No. 272.

Studies on Mechanism of Carbon Monoxide Poisoning as Observed in Dogs Anesthetized With Sodium Amytal. PHB No. 274.

Health and Working Environment of Nonferrous Metal Mine Workers. PHB No. 277.

Medical Study of Men Exposed to Measured Amounts of Carbon Monoxide in Holland Tunnel for 13 Years. PHB No. 278.

Toxicity and Potential Dangers of Toluene, With Special Reference to Its Maximal Permissible Concentration. PHB No. 279.

Aliphatic Alcohols: Their Toxicity and Potential Dangers in Relation to Their Chemical Constitution and Their Fate in Metabolism. PHB No. 281.

Toxicity and Potential Dangers of Pentaeythritol-tetranitrate (PETN). PHB No. 282.

Experimental Studies on Toxicity and Potential Dangers of Trinitrotoluene (TNT) PHB No. 285.

Carbon Monoxide: Its Hazards and Mechanism of Its Action. PHB No. 290.

Medical Study of Effect of TNT on Workers in a Bomb and Shell Loading Plant. PHB No. 291.

Toxicity of Molybdenum. PHB No. 293.

Control of Ringworm of Scalp Among School Children. PHB No. 294.

Health of Arc Welders in Steel Ship Construction. PHB No. 298.

American Industrial Hygiene Association
— News of Local Sections —

New England Section

THE NEW ENGLAND Section of the American Industrial Hygiene Association held its Annual Meeting in Portsmouth on October 20.

At the business meeting following the general meeting, officers were elected for the year 1951. These are: DR. JAMES P. DEERY, Rhode Island Department of Health, chairman, and DR. LESLIE SILVERMAN, Harvard School of Public Health, secretary-treasurer.

The following program was presented by the local section:

Presiding: FREDERICK J. VINTINNER, SC.D., Director, Division of Industrial Hygiene, New Hampshire State Health Department, Concord, New Hampshire.

Cyclone Dust Collector Performance by MELVIN W. FIRST, SC.D., Research Associate, School of Public Health, Harvard University.

Silicosis in the Mining and Milling of Slate by RICHARD H. MANSUR, Maine State Department of Health and Welfare.

The Possibility of Coccidiodomycosis and Q Fever Being Occupational Diseases in the Wool Industry by C. M. MALOOF, M.D., Division of Occupational Hygiene, Massachusetts Department of Labor and Industries.

Studies on the Toxicity of Sulfuric Acid Mist by DR. MARY O. AMDUR, School of Public Health, Harvard University.

Tour of Schiller Mercury Vapor Power Plant, Public Service Company, Portsmouth, New Hampshire.

Response of Human Subjects to Acute Chilling in Ice Water and to Fast and Slow Rewarming by PROFESSOR C. P. YAGLOU, School of Public Health, Harvard University.

Radiation Hazards in Industry and in the Medical Field by W. R. LAROCQUE, Industrial Hygienist, Liberty Mutual Insurance Co., Boston, Massachusetts.

The Position of Industrial Hygiene and Occupational Medicine in Scandinavia and Holland as of 1950 by M. GENEVA GRAY, PH.D., Director of Laboratory of Industrial Toxicology, Arthur D. Little, Inc., Cambridge, Massachusetts.

Industrial Hygiene Activities in Peru by AMEDEE S. LANDRY, Chemist, Institute of Inter-American Affairs.

Northern California Section

THE REGULAR meeting of the Northern California Section was held on September 26. DR. FISHLER of the Biomedical Branch of the Navy's Radiological Defense Laboratory was the speaker. He discussed the prevention of injuries due to atomic radiation and detailed the work being done in regard to prophylaxis and therapy in the field of radiation. He stressed the importance of shielding and cited animal experiments which indicated clearly that shielding is a potent safeguard in dealing with atomic radiation.

THE SECTION held its annual meeting on November 21, 1950, at Berkeley, California.

New officers were elected, as follows: President-Elect, DR. EDWARD E. DART; Secretary-Treasurer, A. C. BLACKMAN; and Executive Committee, OSCAR J. SOBOL.

PAUL MAGILL of Stanford Research Institute gave a very comprehensive talk on the problem of air pollution specifically in the Los Angeles area.

Philadelphia Section

ON SEPTEMBER 12, H. T. Walworth, Director, Division of Industrial Hygiene, Lumbermens Mutual Casualty Company, Chicago, Illinois, spoke on "The Role of the Insurance Company in the Field of Industrial Hygiene."

On November 14, at the section meeting of the Engineer's Club, DR. VICTOR H. KINDSVATTER, Industrial Hygienist, Philadelphia Naval Ship Yard, discussed "Some Problems of Radiological Defense."

Rocky Mountain Section

THE ANNUAL MEETING of the Rocky Mountain Section was held in Pueblo, Colorado, on October 20.

The following men were elected officers for the coming year:

President-Elect: SHERMAN S. PINTO, M.D., American Smelting & Refining Co., First National Bank Building, Denver, Colorado.

Secretary-Treasurer: WILLIAM A. MCGILVRAY, Division of Industrial Medicine, University of Colorado Medical Center, Denver, Colorado.

Director: ROBERT S. GRIER, M.D., Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Other officers elected previously and holding office for 1951 are:

President: THOMAS L. SHIPMAN, M.D., Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Director: W. E. JONES, Climax Molybdenum Company, Climax, Colorado.

STATEMENT of the ownership, management, and circulation required by the Act of Congress of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233) of American Industrial Hygiene Association Quarterly published quarterly at Sheboygan, Wisconsin for the calendar year 1951. 1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Industrial Medicine Publishing Company, 605 North Michigan Avenue, Chicago, 11, Illinois, Editor, Herbert J. Weber, c/o American Brake Shoe Company, 2501 Blue Island Ave., Chicago, Illinois, Managing Editor, (none), Business Manager, (none). 2. The owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual member, must be given.) The American Industrial Hygiene Association (a non-incorporated association), Henry F. Smyth, Jr., Executive Secretary, Mellon Institute, Pittsburgh, 13, Pa. 3. The known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None. 4. Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner. American Industrial Hygiene Association, Henry F. Smyth, Jr., Executive Secretary. Sworn to and subscribed before me this 5th day of October, 1950. (Seal) H. C. Davies, Notary Public.

American Industrial Hygiene Association
—News of Local Sections—

Chicago Section

THE DECEMBER meeting of the Chicago Section was addressed by B. E. KUECHLE, Vice President and Manager of Claims, Employers Mutual Liability Company, Wausau, Wisconsin, and GEORGE W. MARSALEK of Moser, Marsalek, Carpenter, Cleary and Carter, Attorneys, St. Louis, Missouri. The subject of the meeting was "Medico-Legal Aspects of Industrial Hygiene, Industrial Medicine, Industrial Nursing and Insurance."

On January 4, 1950 W. G. HAZARD of the Owens-Illinois Glass Company of Toledo, Ohio gave an interesting talk on "Radiant Heat" before the Chicago Section.

Michigan Section

IN NOVEMBER, DR. P. C. CAMPBELL, JR., of the Dermatoses Section of the U.S. Public Health Service, Industrial Hygiene Division, addressed the Michigan Industrial Hygiene Society.

In December, a pre-holiday social and dinner was held.

To serve the Michigan Section during the 1949-1950 season, IRA AVRIN, M.D., was elected President; VICTOR B. SARKISSIAN, Secretary-Treasurer. W. G. FREDRICK, SC.D., is Past President. E. F. LUTZ, M.D., J. C. RADCLIFFE, R. G. SMITH and D. G. FOWLER compose the Executive Committee.

Georgia Section

DR. IRVING TABERSHAW, Columbia University School of Health was the guest speaker at the November meeting of the Georgia Section. The meeting was a culmination of a project begun in 1946 to promote interest in a Cooperative Industrial Health Center for small industries in the Atlanta area.

DR. ANNA M. BAETJER, Professor of Physiological Hygiene, Johns Hopkins University was scheduled as guest speaker at the January meeting. Her subject: "Women in Industry, Their Health and Efficiency."

Metropolitan New York Section

ON FEBRUARY 8, 1950, "Developments in the Industrial Hygiene Aspects of Beryllium" was the scheduled subject of three speakers: JOHN H. HARLEY, U.S. Atomic Energy Commission, the Chemical Aspect; ALFRED J. BRESLIN, U.S. Atomic Energy Commission, the Engineering Aspect; and JOHN E. SILSON, M.D., New York State Department of Labor, the Medical Aspect.

Northern California Section

THE REGULAR quarterly meeting of the Northern California Section was held January 17, at DiMaggio's Restaurant in San Francisco. Members were invited to introduce their guests, among whom were C. R. WALMER, M.D., Industrial Hygiene Foundation and L. V. TAYLOR, American Can Company. DR. DAVE HOLADAY, former Chief, Bureau of Disease Control, State Department of Public Health, now Medical Director for American Can Company was also introduced.

DR. VICTOR BOND, Research Associate of the Naval Radiological Defense Laboratory, San Francisco, gave a very interesting and informative talk on "Radiation Sickness."

Philadelphia Section

ON JANUARY 10, 1950, ARTHUR C. STERN, Chief of the Industrial Hygiene Engineering Unit of the Division of Industrial Hygiene and Safety Standards New York State Department of Labor, addressed the Philadelphia section in January on "Solving Some Industrial Ventilation Problems."

St. Louis Section

ON NOVEMBER 22 WILLIAM B. HARRIS, Chief Industrial Hygiene Section, Health and Safety Branch, New York Operating Office, U.S. Atomic Energy Commission addressed the section on the subject "Meteorology Applications in Air Pollution Studies."

Washington-Baltimore Section

ON DECEMBER 14, 1949 a dinner meeting was held at the Officers' Club, Naval Gun Factory, Washington, D.C. ALLEN D. BRANDT, SC.D., of the Bethlehem Steel Company discussed "Industrial Hygiene Problems in the Steel Industry."

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

Committees

Auditing
H. M. Chapman
Industrial Hygiene Foundation
S. J. Pearce
U. S. Bureau of Mines

Awards
W. A. Cook, Chairman
Zurich Insurance Company
J. J. Bloomfield
U. S. Public Health Service
H. H. Schrenk
Industrial Hygiene Foundation

Education
W. C. Hodge, Chairman
University of Rochester
W. F. Ashe
University of Cincinnati
A. M. Baetjer
The Johns Hopkins University
T. F. Hatch
University of Pittsburgh
W. C. L. Hemeon
Industrial Hygiene Foundation
A. J. Lanza
N. Y. Univ. Bellevue Medical Center
L. Silverman
Harvard School of Public Health

Local Sections
H. W. Speicher, Chairman
Westinghouse Electric Corporation
L. J. Cralley
U. S. Public Health Service
J. W. Hammond
Humble Oil & Refining Company
D. D. Irish
Dow Chemical Company

Membership
J. F. Treon, Chairman
Kettering Lab., Univ. of Cincinnati
L. V. Cralley
Aluminum Research Laboratories
K. R. Doremus
Lumbermens Mutual Casualty Co.
F. L. Oglesby
Tennessee-Eastman Corporation
H. F. Schulte
University of California, Los Alamos
J. H. Sterner
Eastman Kodak Company
B. D. Tebbens
University of California

Nominating
E. C. Barnes, Chairman
Westinghouse Electric Corporation
W. A. Cook
Zurich Insurance Company
F. A. Patty
General Motors Corporation

Personnel Placement
F. W. Sands, Chairman
U. S. Rubber Company
R. A. Kehoe
University of Cincinnati
L. M. Petrie
Georgia Department of Public Health
H. H. Schrenk
Industrial Hygiene Foundation
L. Silverman
Harvard School of Public Health

Program
A. M. Baetjer, Chairman
The Johns Hopkins University
F. S. Mallette
American Steel and Wire Company
J. C. Radcliffe
Ford Motor Company
C. R. Williams
Liberty Mutual Insurance Company

Publicity
J. B. Gisclard, Chairman
American Cyanamid Company
J. T. Gresh
American Brake Shoe Company
L. B. F. Raycroft
Philadelphia Safety Council
L. V. Taylor
American Can Company
W. F. Weber
Western Electric Company

Tellers
S. J. Pearch, Chairman
U. S. Bureau of Mines
J. H. Holden
Pittsburgh Testing Laboratory
J. F. Morgan
Industrial Hygiene Foundation

Annual Conference
N. F. Hendricks, Chairman
Standard Oil Company (N. J.)
W. B. Bradley, Co-Chairman
American Cyanamid Company

Arrangements
C. M. Berry, Chairman
Esso Standard Oil Corporation
A. E. Dooley
The Texas Company
J. W. Fehnel
Metropolitan Life Insurance Co.
W. B. Harris
U. S. Atomic Energy Commission
E. L. Schall
N. J. State Department of Health

Banquet
W. F. Weber, Chairman
Western Electric Company
W. E. Shoemaker
American Mutual Liability Ins. Co.
L. F. Weller
N. J. Department of Health